

Chemical Equilibrium

Given:

- Reaction: $2 \text{NO(g)} \rightleftharpoons 2 \text{NO}_2\text{(g)} + \text{O}_2\text{(g)}$
- $K_P = 1.11 \times 10^{-5}$ at 200°C
- Volume of the vessel, $V = 2.50 \text{ L}$
- Initial pressure of NO, $P_{\text{initial, NO}} = 4.00 \text{ atm}$

Introduction:

The goal is to find the pressure of NO(g) at equilibrium when the initial pressure is given, and the system is allowed to come to equilibrium.

Step 1: Write the stoichiometric expression and initial pressures

Initial:



Initially, the pressure of NO is 4.00 atm. There are no NO₂ and O₂ present initially.

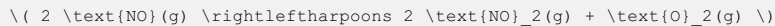
Pressure of:

- NO = 4.00 atm
- NO₂ = 0 atm
- O₂ = 0 atm

Explanation: The initial setup involves introducing NO into the vessel with no initial NO₂ or O₂.

Step 2: Setup the expression for changes and equilibrium pressures

Change:



Let us denote the change in pressure of NO that reacts to form NO₂ and O₂ be x atm.

Changes in pressure:

- Pressure of NO: $4.00 - 2x \text{ atm}$
- Pressure of NO₂: $0 + 2x \text{ atm}$
- Pressure of O₂: $0 + x \text{ atm}$

Explanation: Based on the stoichiometry, for every decrease of 2x atm in NO, NO₂ increases by 2x atm and O₂ increases by x atm.

Step 3: Write the expression for K_P using the equilibrium pressures

At equilibrium:

- Pressure of NO: $4.00 - 2x \text{ atm}$
- Pressure of NO₂: $2x \text{ atm}$
- Pressure of O₂: $x \text{ atm}$

Now write the equilibrium expression for K_P :

$$K_P = \frac{(P_{\text{NO}_2})^2 (P_{\text{O}_2})}{(P_{\text{NO}})^2}$$

Substitute the equilibrium pressures:

$$1.11 \times 10^{-5} = \frac{(2x)^2 (x)}{(4.00 - 2x)^2}$$
$$1.11 \times 10^{-5} = \frac{4x^3}{(4.00 - 2x)^2}$$

Rearranging for solving,

$$1.11 \times 10^{-5} = \frac{4x^3}{(16 - 16x + 4x^2)}$$

Multiply both sides by $(16 - 16x + 4x^2)$ to clear the denominator:

$$1.11 \times 10^{-5} \times (16 - 16x + 4x^2) = 4x^3$$

Simplify and solve for x .

Explanation: Substituting equilibrium pressures into K_P expression and rearranging allows solving for the change in pressure x .

Step 4: Solve the equation for x and find the pressures

Let's solve:

$$1.11 \times 10^{-5} (16 - 16x + 4x^2) = 4x^3$$

```

Approximating:
\ ( 1.78 \times 10^{-4} - 1.78 \times 10^{-4}x + 4.44 \times 10^{-5} x^2 = x^3 \ )

This is a cubic equation in \ ( x \ ). Solving numerically or graphically, assuming \ ( x \ ) is
small due to small \ ( K_P \ ):
Approximating,
\ ( 1.78 \times 10^{-4} \approx 4x^3 \ )

\ ( x^3 \approx \frac{1.78 \times 10^{-4}}{4} \ )
\ ( x^3 \approx 4.45 \times 10^{-5} \ )
\ ( x \approx \sqrt[3]{4.45 \times 10^{-5}} \ )
\ ( x \approx 0.035 \ , \ \text{atm} \ )

Finally, the equilibrium pressure of NO:
\ ( P_{\text{equilibrium, NO}} = 4.00 - 2x \approx 4.00 - 2(0.035) \approx 3.93 \ , \ \text{atm} \ )
\ )

```

***Explanation*:** Solving the cubic equation for x and substituting to find equilibrium pressure of NO.

Final Solution:

The pressure of NO(g) at equilibrium is approximately **3.93 atm**