Log Rate vs. pH Linear Relationship

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Response: To find the correct graph representing $\log(\text{Initial rate})$ versus pH, we can derive the relationship using chemical kinetics:

1. Rate Equation for the Elementary Reaction

Since the reaction $\text{A(aq)} + \text{H}_3\text{O}^+\text{(aq)} \rightarrow \text{B}^+\text{(aq)}$ is **elementary**, its rate law directly follows its stoichiometry:

$$\text{Initial Rate } (R) = k[\text{A}][\text{H}_3\text{O}^+]$$

Where:

- k is the rate constant (constant at a fixed temperature).
- $[\text{A}]$ is constant as specified in the problem.

2. Expressing in Logarithmic Form

Taking the base-10 logarithm ($\log$) of both sides of the rate equation:

$$\log(R) = \log(k) + \log([\text{A}]) + \log([\text{H}_3\text{O}^+])$$

3. Incorporating pH

By definition, $\text{pH} = -\log([\text{H}_3\text{O}^+])$, which means $\log([\text{H}_3\text{O}^+]) = -\text{pH}$.

Substituting this into the logarithmic rate equation:

$$\log(R) = (\log(k) + \log([\text{A}])) - \text{pH}$$

Since $\log(k) + \log([\text{A}])$ is a constant (C):

$$\log(R) = -\text{pH} + C$$

Conclusion

Comparing this equation to the equation of a straight line, $y = mx + c$:

- **y-axis:** $\log(\text{Initial rate})$
- **x-axis:** pH
- **Slope (m):** -1 (a negative linear relationship)

The graph of $\log(\text{Initial rate})$ versus pH is a **straight line with a negative slope**.

Correct Answer: (5)