Buffer pH Calculation With Added Acid

https://gemini.google.com/app/8568dcaec1be2d35

Response: Here is the step-by-step solution to the problem:

Step-by-Step Calculation

1. Initial State of the Buffer

- **Weak acid concentration ($[\text{HA}]_0$):** 0.10 mol dm^{-3}
- **Sodium salt concentration ($[\text{A}^-]_0$):** 0.10 mol dm^{-3}
- **Dissociation constant (K_a):** $1.00 \times 10^{-5} \text{ mol dm}^{-3}$

$$\text{p}K_a = -\log_{10}(1.00 \times 10^{-5}) = 5.0$$

Using the Henderson-Hasselbalch equation:

$$\text{pH} = \text{p}K_a + \log_{10}\left(\frac{[\text{A}^-]}{[\text{HA}]}\right)$$

$$\text{pH}_{\text{initial}} = 5.0 + \log_{10}\left(\frac{0.10}{0.10}\right) = 5.0$$

2. Final pH After Adding Acid

Adding extra acid makes the solution more acidic, so the pH will decrease by 1 unit:

$$\text{pH}_{\text{final}} = 5.0 - 1.0 = 4.0$$

3. Moles in the Initial 10.00 cm^3 Buffer Solution

- **Initial volume (V_0):** $10.00 \text{ cm}^3 = 0.010 \text{ dm}^3$
- **Moles of acid ($n_{\text{HA},0}$):** $0.10 \text{ mol dm}^{-3} \times 0.010 \text{ dm}^3 = 1.0 \times 10^{-3} \text{ mol}$
- **Moles of conjugate base ($n_{\text{A}^-}, 0$):** $0.10 \text{ mol dm}^{-3} \times 0.010 \text{ dm}^3 = 1.0 \times 10^{-3} \text{ mol}$

4. Moles of Added Weak Acid

Let $V \text{ (in cm}^3)$ be the volume of 1.00 mol dm^{-3} weak acid added.

- **Moles of added acid (n_{added}):** $1.00 \times \frac{V}{1000} = 10^{-3} V \text{ mol}$

Total moles of weak acid in the mixture ($n_{\text{HA,total}}$):

$$n_{\mathrm{HA,total}} = 1.0 \times 10^{-3} + 10^{-3}V = 10^{-3}(1+V)\ \mathrm{mol}$$

The amount of conjugate base (n_{A^-}) remains unchanged:

$$n_{\mathrm{A}^-} = 1.0 \times 10^{-3}\ \mathrm{mol}$$

5. Calculate Added Volume (V)

Using the Henderson-Hasselbalch equation for the final state:

$$\mathrm{pH}_{\mathrm{final}} = \mathrm{p}K_a + \log_{10}\left(\frac{n_{\mathrm{A}^-}}{n_{\mathrm{HA,total}}}\right)$$

$$4.0 = 5.0 + \log_{10}\left(\frac{1.0 \times 10^{-3}}{10^{-3}(1+V)}\right)$$

$$-1.0 = \log_{10}\left(\frac{1}{1+V}\right)$$

$$10^{-1} = \frac{1}{1+V} \implies \frac{1}{10} = \frac{1}{1+V}$$

$$1 + V = 10 \implies V = 9.00\ \mathrm{cm}^3$$

Conclusion

- **Volume of weak acid to add:** $9.00\ \mathrm{cm}^3$
- **New pH value:** 4.0

Correct Option: (1) $9.00\ \mathrm{cm}^3, 4.0$
