Exercise walk-through

Weak Acid and Base Equilibria ▪ 8.3

eXercise

You must be able to

- write the K_a (or K_b) expression
- use an ICE table with the small-x approximation
- find the pH of a weak acid

Method — The acid-dissociation constant

For $HA \rightleftharpoons H^+ + A^-$:

$$K_a = \frac{[H^+][A^-]}{[HA]}.$$

A **small** K_a means a weak acid (little ionization).

Method — The ICE + approximation

Start $[\mathrm{HA}] = C$, $[\mathrm{H}^+] = [\mathrm{A}^-] = 0$; change $-x, +x, +x$. With x small, $C - x \approx C$, so

$$K_a \approx \frac{x^2}{C} \;\Rightarrow\; x = \sqrt{K_a C} = [\mathrm{H}^+].$$

Method — A worked pH

0.10 M acid, $K_a = 1.8 \times 10^{-5}$:
$x = \sqrt{(1.8 \times 10^{-5})(0.10)} = \sqrt{1.8 \times 10^{-6}} = 1.34 \times 10^{-3}$, so
pH $= -\log(1.34 \times 10^{-3}) = 2.87$.

Method — Bases use Kb

For a weak base, $K_b = \dfrac{[BH^+][OH^-]}{[B]}$, and the same method gives $[OH^-]$, then pOH and pH.

Practice 2.1 ▪ 1 mark

Write the K_a expression for $\mathrm{HF} \rightleftharpoons \mathrm{H}^+ + \mathrm{F}^-$.

Solution 2.1

Method: The acid-dissociation constant

Worked steps

$$K_a = \frac{[H^+][F^-]}{[HF]} \quad \textbf{B1}.$$

Practice 2.2 ▪ 1 mark

Does a small K_a mean a strong or weak acid?

Solution 2.2

Method: The acid-dissociation constant

Worked steps

Weak **B1**.

Practice 2.3 ▪ 2 marks

For 0.10 M acid with $K_a = 4 \times 10^{-7}$, use $x = \sqrt{K_a C}$ to find $[\mathrm{H}^+]$.

Solution 2.3

Method: A worked pH

Worked steps

$x = \sqrt{(4 \times 10^{-7})(0.10)} = \sqrt{4 \times 10^{-8}} = 2 \times 10^{-4}$ M **M1** **A1**.

Exam-style 3.1 ▪ 1 mark

For a weak acid, $[\mathrm{H}^+] \approx$

A K_a

B $\sqrt{K_a C}$

C C

D $K_a C$

Solution 3.1

Method: The acid-dissociation constant

A K_a

B $\sqrt{K_a C}$ ✓

C C

D $K_a C$

Worked steps

B — $[\mathrm{H}^+] \approx \sqrt{K_a C}$.

Exam-style 3.2 ▪ 2 marks

A 0.20 M solution of a weak acid has $K_a = 1.0 \times 10^{-5}$.
(a) Find $[\text{H}^+]$ using the approximation.
(b) Find the pH.

Solution 3.2

Worked steps

(a) $[\mathrm{H}^+] = \sqrt{(1.0 \times 10^{-5})(0.20)} = \sqrt{2.0 \times 10^{-6}} = 1.41 \times 10^{-3}$ M **M1** **A1**. (b) pH $= -\log(1.41 \times 10^{-3}) = 2.85$ **M1** **A1**.

Exam-style 3.3 ▪ 2 marks

Explain why the small-x approximation is valid for a weak acid but not for a strong acid.

Solution 3.3

Method: The acid-dissociation constant

Worked steps

A weak acid ionizes only slightly, so x is tiny compared to C and $C - x \approx C$; a strong acid ionizes fully, so $x \approx C$ and the approximation fails **M1** **A1**.