Exercise walk-through

Calculating Equilibrium Concentrations ▪ 7.7

eXercise

You must be able to

- set up an **ICE table** with an unknown change x
- substitute into K and solve for x
- use a valid **approximation** when K is small

Method — ICE with unknown x

Write the change as x (times each coefficient), fill the equilibrium row, and substitute into K. For A $\rightleftharpoons$ B, start $[\mathrm{A}] = 1.0$, $K = 3$: equilibrium $[\mathrm{A}] = 1 - x$, $[\mathrm{B}] = x$; $\dfrac{x}{1 - x} = 3 \Rightarrow x = 0.75$.

Method — Solving the algebra

Cross-multiply and solve. Reject any root that gives a **negative** concentration — only physically sensible values are valid.

Method — The small-K approximation

When K is very small, the change x is tiny, so $[\mathrm{A}]_{\mathrm{start}} - x \approx [\mathrm{A}]_{\mathrm{start}}$. This avoids the quadratic. Check that x is under ~5% of the start.

Method — A worked approximation

$\mathrm{HA} \rightleftharpoons \mathrm{H}^+ + \mathrm{A}^-$, start $[\mathrm{HA}] = 0.10$, $K = 1 \times 10^{-5}$: assume $0.10 - x \approx 0.10$, so $x^2/0.10 = 10^{-5}$, $x = \sqrt{10^{-6}} = 10^{-3}$.

Practice 2.1 ▪ 1 mark

In an ICE table, if [A] decreases by x, what is [A] at equilibrium (start $= 0.5$)?

Solution 2.1

Method: ICE with unknown x

Worked steps

$0.5 - x$ **B1**.

Practice 2.2 ▪ 1 mark

Why reject a negative value of x?

Solution 2.2

Method: Solving the algebra

Worked steps

A concentration cannot be negative — it is unphysical **B1**.

Practice 2.3 ▪ 1 mark

When is the small-K approximation valid?

Solution 2.3

Method: The small-K approximation

Worked steps

When K is very small, so x is under about 5% of the starting concentration **B1**.

Exam-style 3.1 ▪ 1 mark

The small-x approximation assumes the change is

A large compared to the starting concentration

B small compared to the starting concentration

C exactly zero

D negative

Solution 3.1

Method: The small-K approximation

A large compared to the starting concentration

B small compared to the starting concentration ✓

C exactly zero

D negative

Worked steps

B — small compared to the starting concentration.

Exam-style 3.2 ▪ 2 marks

For A $\rightleftharpoons$ B, start $[\text{A}] = 2.0$ M, $[\text{B}] = 0$, $K = 1.0$.
(a) Set up the ICE expression in terms of x.
(b) Solve for x and give the equilibrium concentrations.

Solution 3.2

Method: ICE with unknown x

Worked steps

(a) $[\mathrm{A}] = 2 - x$, $[\mathrm{B}] = x$; $K = \dfrac{x}{2 - x} = 1.0$ **M1** **A1**. (b) $x = 2 - x \Rightarrow 2x = 2 \Rightarrow x = 1.0$; so $[\mathrm{A}] = [\mathrm{B}] = 1.0$ M **M1** **M1** **A1**.

Exam-style 3.3 ▪ 3 marks

A weak acid HA $\rightleftharpoons$ $H^+ + A^-$ has $K = 4 \times 10^{-6}$ and start $[HA] = 0.10$ M. Using the small-x approximation, find $[H^+]$.

Solution 3.3

Method: A worked approximation

Worked steps

$\frac{x^2}{0.10} \approx 4 \times 10^{-6}$ **M1**; $x^2 = 4 \times 10^{-7}$, $x = 6.3 \times 10^{-4}$ **M1**; $[\mathrm{H}^+] = 6.3 \times 10^{-4}$ M **A1**.