

7.7 Calculating Equilibrium Concentrations

Name: _____ Class: _____ Date: _____ **Total: 12 marks**

Objective

Build the skills to answer exam questions on **calculating equilibrium concentrations** with an ICE table.

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

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ 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 $[A] = 1.0$, $K = 3$: equilibrium $[A] = 1 - x$, $[B] = x$;

$$\frac{x}{1 - x} = 3 \Rightarrow x = 0.75.$$

■ Solving the algebra

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

■ The small- K approximation

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

■ A worked approximation

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

2 Practice

Now apply the methods above.

2.1 In an ICE table, if $[A]$ decreases by x , what is $[A]$ at equilibrium (start = 0.5)? [1]

2.2 Why reject a negative value of x ? [1]

2.3 When is the small- K approximation valid? [1]

3 Exam-style questions

3.1 The small- x approximation assumes the change is [1]

- **A** large compared to the starting concentration
- **B** small compared to the starting concentration
- **C** exactly zero
- **D** negative

3.2 For $A \rightleftharpoons B$, start $[A] = 2.0$ M, $[B] = 0$, $K = 1.0$.

(a) Set up the ICE expression in terms of x . [2]

(b) Solve for x and give the equilibrium concentrations. [3]

3.3 A weak acid $\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-$ has $K = 4 \times 10^{-6}$ and start $[\text{HA}] = 0.10 \text{ M}$. Using the small- x approximation, find $[\text{H}^+]$. [3]

Solutions

2.1 $0.5 - x$.

2.2 A concentration cannot be negative — it is unphysical.

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

3.1 B — small compared to the starting concentration.

3.2 (a) $[\text{A}] = 2 - x$, $[\text{B}] = x$; $K = \frac{x}{2 - x} = 1.0$. (b) $x = 2 - x \Rightarrow 2x = 2 \Rightarrow x = 1.0$; so $[\text{A}] = [\text{B}] = 1.0 \text{ M}$.

3.3 $\frac{x^2}{0.10} \approx 4 \times 10^{-6}$; $x^2 = 4 \times 10^{-7}$, $x = 6.3 \times 10^{-4}$; $[\text{H}^+] = 6.3 \times 10^{-4} \text{ M}$.