AP CHEMISTRY • EXERCISE SHEET

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] $= x$; $\dfrac{x}{1-x} = 3 \Rightarrow x = 0.75$.

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 $[A]_{start} - x \approx [A]_{start}$. 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]

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

4 Go further

You are now ready for the real exam questions on this subtopic:

- work through the **7.7 Calculating Equilibrium Concentrations** lesson on the **Learn** page;
- read the **Calculating Equilibrium Concentrations** section of the AP Chemistry handout on the **Know** page.

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

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