7.7 Calculating Equilibrium Concentrations

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

KEY WORDS ICE table ICE • small-x approximation • equilibrium concentration • unknown • valid • percent

Objective

Build the skills to answer exam questions on **calculating equilibrium concentrations** : ICE tables with x, and the small-x approximation when K is small.

You must be able to:

- set up an ICE table with an unknown change x
- write the K expression in terms of x
- use the **small-x approximation** when K is very small, and check it (less than 5%)
- find each equilibrium concentration from x

1 Key knowledge and worked examples

■ **Solving for x**

step	what to do
1	ICE table: the changes are $-x$, $+x$, $+2x$, etc., from the coefficients
2	put the equilibrium row into the K expression
3	if K is very small, $c - x \approx c$ (this makes the algebra easy)
4	solve for x, then find every concentration
5	check: $\frac{x}{c} \times 100\%$ should be under 5%

Worked example: a weak dissociation. $\mathrm{AB} \rightleftharpoons \mathrm{A} + \mathrm{B}$, $K_c = 4.0 \times 10^{-6}$, $[\mathrm{AB}]_0 = 0.10$ M.

1. $\frac{x^2}{0.10 - x} \approx \frac{x^2}{0.10} = 4.0 \times 10^{-6}$, so $x^2 = 4.0 \times 10^{-7}$ and $x = 6.3 \times 10^{-4}$ M.
2. Check: $\frac{6.3 \times 10^{-4}}{0.10} = 0.63\%$, under 5%: **the approximation is fine**.

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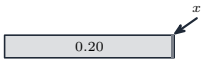
Answer shapes: show the ICE table, the expression in x, the approximation and the check.

2 Practice

2.1 0.50 M of A is placed in a flask: $\mathrm{A(g)} \rightleftharpoons 2\mathrm{B(g)}$. Write the equilibrium concentrations of A and B in terms of x, and the K_c expression in terms of x. [2]

	A	B
I	0.50	0
C		
E		

2.2 Explain why $0.20 - x$ can be replaced by 0.20 when K_c is very small. [2]



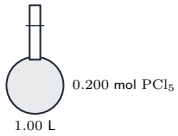
2.3 Solve $\frac{x^2}{0.10} = 1.0 \times 10^{-5}$ for x. [2]



3 Exam-style questions

3.1 0.200 mol of PCl_5 is placed in a 1.00 L flask: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$, $K_c = 1.8 \times 10^{-5}$ at this temperature.

(a) Write the equilibrium concentrations in terms of x, and the K_c expression in terms of x. [2]



(b) Use the small-x approximation to find $[Cl_2]$ at equilibrium. [2]

(c) Show that the approximation is valid. [2]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

$[\mathrm{A}] = 0.50 - x$, $[\mathrm{B}] = 2x$; $K_c = \dfrac{(2x)^2}{0.50 - x}$

2.2

a very small K means very little reacts; so x is tiny compared with 0.20 and hardly changes it

2.3

$x^2 = 1.0 \times 10^{-6}$; $x = \mathbf{1.0 \times 10^{-3}}$

3.1

(a) $[\mathrm{PCl_5}] = 0.200 - x$, $[\mathrm{PCl_3}] = [\mathrm{Cl_2}] = x$; $K_c = \dfrac{x^2}{0.200 - x}$

(b) $x^2 = 1.8 \times 10^{-5} \times 0.200 = 3.6 \times 10^{-6}$; $[\mathrm{Cl_2}] = x = \mathbf{1.9 \times 10^{-3}\ M}$

(c) $\dfrac{1.9 \times 10^{-3}}{0.200} \times 100\% = 0.95\%$; this is under 5%, so the approximation is valid

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