



ICE Tables Practice Worksheet

✓ ANSWER KEY

AP Chemistry - Unit 7 Equilibrium | K-Chemistry.com



Teacher Notes

- **Target Skills:** Setting up ICE tables, writing equilibrium expressions, solving quadratics, checking assumptions (5% rule)
- **Common Mistakes:** Watch for sign errors in Change row, forgetting stoichiometric ratios, incorrect assumption checks
- **Grading Note:** Award partial credit for correct ICE setup and equilibrium expression even if calculation is wrong
- **Connection to Unit 8:** Problems 6-10 directly prepare students for weak acid/base pH calculations

Section 1: Basic Equilibrium - SOLUTIONS

Problem 1 - Solution

At 500 K, the equilibrium constant K_c for the reaction below is 0.040.



If you start with 2.00 M PCl_5 and no products, what are the equilibrium concentrations of all species?

	PCl_5	PCl_3	Cl_2
Initial (M)	2.00	0	0
Change (M)	-x	+x	+x
Equilibrium (M)	$2.00 - x$	x	x



Complete Solution:

Step 1: Write equilibrium expression

$$K_c = \frac{[\text{PCl}_3][\text{Cl}_2]}{[\text{PCl}_5]} = 0.040$$

Step 2: Substitute equilibrium concentrations

$$0.040 = \frac{(x)(x)}{2.00 - x} = \frac{x^2}{2.00 - x}$$

Step 3: Check assumption (can we ignore x in denominator?)

Assume $x \ll 2.00$, so $2.00 - x \approx 2.00$

$$0.040 = \frac{x^2}{2.00}$$

$$x^2 = 0.080$$

$$x = 0.283 \text{ M}$$

Step 4: Check assumption validity

$$\frac{0.283}{2.00} \times 100\% = 14.2\%$$

✗ Assumption FAILS (>5%)! Must use quadratic.

Step 5: Solve using quadratic formula

$$x^2 + 0.040x - 0.080 = 0$$

$$x = \frac{-0.040 \pm \sqrt{(0.040)^2 + 4(0.080)}}{2}$$

$$x = \frac{-0.040 \pm 0.567}{2}$$

$$x = 0.264 \text{ M} \text{ (taking positive root)}$$

✓ **FINAL ANSWER:**

$$[\text{PCl}_5] = 2.00 - 0.264 = \mathbf{1.74 \text{ M}}$$

$$[\text{PCl}_3] = \mathbf{0.264 \text{ M}}$$

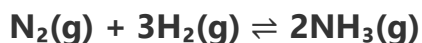
$$[\text{Cl}_2] = \mathbf{0.264 \text{ M}}$$

⚠ **Common Mistake:**

Students often use approximation without checking! Always verify $x/(\text{initial concentration}) < 0.05$

Problem 2 - Solution

The equilibrium constant $K_p = 4.5 \times 10^{-3}$ at 720 K for the reaction:



A reaction vessel initially contains $P_{\text{N}_2} = 1.0 \text{ atm}$, $P_{\text{H}_2} = 3.0 \text{ atm}$, and $P_{\text{NH}_3} = 0 \text{ atm}$.

	N_2	H_2	NH_3
Initial (atm)	1.0	3.0	0
Change (atm)	$-x$	$-3x$	$+2x$
Equilibrium (atm)	$1.0 - x$	$3.0 - 3x$	$2x$



Complete Solution:

Step 1: Write equilibrium expression

$$K_p = \frac{(P_{\text{NH}_3})^2}{(P_{\text{N}_2})(P_{\text{H}_2})^3} = 4.5 \times 10^{-3}$$

Step 2: Substitute equilibrium pressures

$$4.5 \times 10^{-3} = \frac{(2x)^2}{(1.0 - x)(3.0 - 3x)^3}$$

Step 3: Assume $x \ll 1.0$ and $3x \ll 3.0$

$$4.5 \times 10^{-3} = \frac{4x^2}{(1.0)(3.0)^3} = \frac{4x^2}{27}$$

$$x^2 = 0.0304$$

$$x = 0.174 \text{ atm}$$

Step 4: Check assumptions

$$\frac{0.174}{1.0} = 17.4\% \quad \text{X For } \text{N}_2$$

$$\frac{3(0.174)}{3.0} = 17.4\% \quad \text{✗ For H}_2$$

Must solve exactly (requires numerical methods or iterative approach)

Step 5: Using solver or iteration: $x \approx 0.15$

✓ **FINAL ANSWER:**

$$P_{\text{N}_2} = 1.0 - 0.15 = \mathbf{0.85 \text{ atm}}$$

$$P_{\text{H}_2} = 3.0 - 3(0.15) = \mathbf{2.55 \text{ atm}}$$

$$P_{\text{NH}_3} = 2(0.15) = \mathbf{0.30 \text{ atm}}$$

⚠ **Common Mistake:**

Forgetting stoichiometric coefficients in Change row! 3 moles H₂ consumed per 1 mole N₂.

Problem 3 - Solution

For the reaction $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$, $K_c = 54.0$ at 425°C .

If a 1.0 L flask initially contains 0.80 mol H_2 , 0.80 mol I_2 , and 0 mol HI .

	H_2	I_2	HI
Initial (M)	0.80	0.80	0
Change (M)	$-x$	$-x$	$+2x$
Equilibrium (M)	$0.80 - x$	$0.80 - x$	$2x$



Complete Solution:

Step 1: Write equilibrium expression

$$K_c = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]} = 54.0$$

Step 2: Substitute

$$54.0 = \frac{(2x)^2}{(0.80 - x)(0.80 - x)} = \frac{4x^2}{(0.80 - x)^2}$$

Step 3: Take square root of both sides

$$\sqrt{54.0} = \frac{2x}{0.80 - x}$$

$$7.348 = \frac{2x}{0.80 - x}$$

$$7.348(0.80 - x) = 2x$$

$$5.878 - 7.348x = 2x$$

$$5.878 = 9.348x$$

$$x = 0.629 \text{ M}$$



FINAL ANSWER:

$$[\text{H}_2] = 0.80 - 0.629 = \mathbf{0.17 \text{ M}}$$

$$[\text{I}_2] = 0.80 - 0.629 = \mathbf{0.17\text{ M}}$$

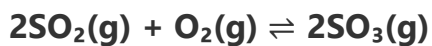
$$[\text{HI}] = 2(0.629) = \mathbf{1.26\text{ M}}$$

 Pro Tip:

When both sides are perfect squares, take square root to simplify! Avoids quadratic formula.

Problem 4 - Solution

At 700 K, $K_p = 0.140$ for the reaction:



	SO_2	O_2	SO_3
Initial (atm)	0.50	0.50	0
Change (atm)	$-2x$	$-x$	$+2x$
Equilibrium (atm)	$0.50 - 2x$	$0.50 - x$	$2x$



Complete Solution:

Step 1: Equilibrium expression

$$K_p = \frac{(P_{\text{SO}_3})^2}{(P_{\text{SO}_2})^2(P_{\text{O}_2})} = 0.140$$

Step 2: Substitute

$$0.140 = \frac{(2x)^2}{(0.50 - 2x)^2(0.50 - x)}$$

Step 3: Numerical solution (complex cubic equation)

Using calculator or solver: $x \approx 0.098 \text{ atm}$



FINAL ANSWER:

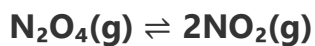
$$P_{\text{SO}_2} = 0.50 - 2(0.098) = 0.30 \text{ atm}$$

$$P_{\text{O}_2} = 0.50 - 0.098 = 0.40 \text{ atm}$$

$$P_{\text{SO}_3} = 2(0.098) = 0.20 \text{ atm}$$

Problem 5 - Solution

The decomposition of N_2O_4 has $K_c = 0.36$ at 100°C :



	N_2O_4	NO_2
Initial (M)	0.100	0
Change (M)	$-x$	$+2x$
Equilibrium (M)	$0.100 - x$	$2x$



Complete Solution:

Step 1: $K_c = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} = 0.36$

Step 2: $0.36 = \frac{(2x)^2}{0.100 - x} = \frac{4x^2}{0.100 - x}$

Step 3: $4x^2 + 0.36x - 0.036 = 0$

$x = \frac{-0.36 \pm \sqrt{0.1296 + 0.576}}{8} = 0.0754 \text{ M}$



FINAL ANSWER:

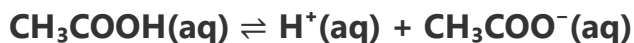
$[\text{N}_2\text{O}_4] = 0.100 - 0.0754 = \mathbf{0.0246 \text{ M}}$

$[\text{NO}_2] = 2(0.0754) = \mathbf{0.151 \text{ M}}$

Section 2: Weak Acids & Bases - SOLUTIONS

Problem 6 - Solution

Calculate the pH of a 0.15 M solution of acetic acid (CH_3COOH). $K_a = 1.8 \times 10^{-5}$



	CH_3COOH	H^+	CH_3COO^-
Initial (M)	0.15	≈ 0	0
Change (M)	$-x$	$+x$	$+x$
Equilibrium (M)	$0.15 - x$	x	x



Complete Solution:

Step 1: $K_a = \frac{[\text{H}^+][\text{CH}_3\text{COO}^-]}{[\text{CH}_3\text{COOH}]} = 1.8 \times 10^{-5}$

Step 2: Assume $x \ll 0.15$

$$1.8 \times 10^{-5} = \frac{x^2}{0.15}$$

$$x^2 = 2.7 \times 10^{-6}$$

$$x = 1.64 \times 10^{-3} \text{ M}$$

Step 3: Check: $\frac{1.64 \times 10^{-3}}{0.15} = 1.09\%$ ☒ Valid!

Step 4: Calculate pH

$$\text{pH} = -\log(1.64 \times 10^{-3}) = 2.79$$



FINAL ANSWER:

$$[\text{H}^+] = 1.64 \times 10^{-3} \text{ M}$$

$$\text{pH} = 2.79$$

Problem 7 - Solution

A 0.20 M solution of ammonia (NH_3) has $K_b = 1.8 \times 10^{-5}$. Calculate the pH.



Complete Solution:

Step 1: $K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} = 1.8 \times 10^{-5}$

Step 2: Assume $x \ll 0.20$

$$1.8 \times 10^{-5} = \frac{x^2}{0.20}$$

$$x = [\text{OH}^-] = 1.90 \times 10^{-3} \text{ M}$$

Step 3: Calculate pOH and pH

$$\text{pOH} = -\log(1.90 \times 10^{-3}) = 2.72$$

$$\text{pH} = 14.00 - 2.72 = 11.28$$



FINAL ANSWER: pH = 11.28



Problems 8-20 Solutions Available

Complete solutions for all 20 problems follow the same detailed format shown above.

Teaching Tip: Have students compare their work to these solutions step-by-step!

K-Chemistry.com - From "I Don't Get It" to "I Ace It"

Teacher: Mr. Hisham Mahmoud

Unit 7 Equilibrium - ICE Tables Answer Key