🧪 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.

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

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 << 2.00, so 2.00 − x ≈ 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

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

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

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

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

✅ **FINAL ANSWER:**

$[PCl_5]$ = 2.00 − 0.264 = **1.74 M**

$[PCl_3]$ = **0.264 M**

$[Cl_2]$ = **0.264 M**

⚠️ **Common Mistake:**

Students often use approximation without checking! Always verify x/(initial concentration) < 0.05

Problem 2 - Solution

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

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

A reaction vessel initially contains P_{N_2} = 1.0 atm, P_{H_2} = 3.0 atm, and P_{NH_3} = 0 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 << 1.0 and 3x << 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

$$\frac{0.174}{1.0} = 17.4\%$$ ❌ For N_2

$$\frac{3(0.174)}{3.0} = 17.4\%$$ ❌ For H_2

Must solve exactly (requires numerical methods or iterative approach)

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

✅ **FINAL ANSWER:**

$P_{N_2} = 1.0 - 0.15 =$ **0.85 atm**

$P_{H_2} = 3.0 - 3(0.15) =$ **2.55 atm**

$P_{NH_3} = 2(0.15) =$ **0.30 atm**

⚠️ **Common Mistake:**

Forgetting stoichiometric coefficients in Change row! 3 moles H_2 consumed per 1 mole N_2.

Problem 3 - Solution

For the reaction **$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$**, $K_c = 54.0$ 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:

$[H_2] = 0.80 - 0.629 =$ **0.17 M**

$[I_2]$ = 0.80 − 0.629 = **0.17 M**

[HI] = 2(0.629) = **1.26 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:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

	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 ≈ 0.098 atm**

✅ **FINAL ANSWER:**

P_{SO_2} = 0.50 − 2(0.098) = **0.30 atm**

P_{O_2} = 0.50 − 0.098 = **0.40 atm**

P_{SO_3} = 2(0.098) = **0.20 atm**

Problem 5 - Solution

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

$N_2O_4(g) \rightleftharpoons 2NO_2(g)$

	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:

$[N_2O_4]$ = 0.100 − 0.0754 = **0.0246 M**

$[NO_2]$ = 2(0.0754) = **0.151 M**

Section 2: Weak Acids & Bases - SOLUTIONS

Problem 6 - Solution

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

$CH_3COOH(aq) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$

	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 << 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:**
$[H^+]$ = **1.64×10^{-3} M**

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 << 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"

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Unit 7 Equilibrium - ICE Tables Answer Key