ExamFitter

examfitter.com · Free AP Chemistry quizzes, revision notes and worksheets

Topic 8.3: Weak Acid and Base Equilibria

Revision Notes · AP Chemistry

UNIT 8 · ACIDS AND BASES

On ExamFitter.com: Topic 8.3 Quiz · Topic 8.3 Worksheet · Unit 8: All Topics · AP Chemistry Home

Partial Ionization and the Two Constants

A weak acid ionizes only partially in water:

$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

That reaction settles with most molecules still CH_3COOH.

The balance is measured by Ka, for this reaction:

$HA + H_2O \rightleftharpoons H_3O^+ + A^-$

$Ka = [H_3O^+][A^-] \div [HA]$

Water, the solvent, is left out of the expression. A small Ka means the equilibrium lies far left and the acid is weak; a strong acid has no working Ka and is handled by counting (Topic 8.2).

Weak bases mirror the pattern:

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

$Kb = [NH_4^+][OH^-] \div [NH_3]$

Larger Ka or Kb means stronger, lying further right at equilibrium.

Constants used here, at 25 °C: HF Ka = 6.8×10^{-4}, HCOOH Ka = 1.8×10^{-4}, CH_3COOH Ka = 1.8×10^{-5}, H_2CO_3 Ka1 = 4.3×10^{-7}, HCN Ka = 4.9×10^{-10}; CH_3NH_2 Kb = 4.4×10^{-4}, NH_3 Kb = 1.8×10^{-5}.

The ICE Table Turns a Constant into a pH

An ICE table follows one number, x, the concentration that ionizes. For C mol L^{-1} of HA: initial row C, 0, 0; change row −x, +x, +x; equilibrium row C − x, x, x. Substituting the equilibrium row gives:

© 2026 ExamFitter.com · Free AP Chemistry revision notes

$K_a = x^2 \div (C - x)$

Here x is $[H_3O^+]$ itself, so one logarithm gives the pH.

For a weak base the same table runs on the base reaction and x is $[OH^-]$; the route to pH passes through pOH, with pH = 14.00 − pOH at 25 °C.

The Small-x Approximation and the 5 Percent Check

When x is tiny beside C, $C - x \approx C$ and the equation collapses to:

$x \approx \sqrt{(K_a \times C)}$

It stands or falls on percent ionization, $(x \div C) \times 100$ percent. At 5 percent or below the neglect is accepted; above 5 percent the quadratic must be solved instead:

$x^2 + K_a x - K_a C = 0$

Working Backwards: A Constant from a Measured pH

A measured pH hands over x directly:

$x = [H_3O^+] = 10^{-pH}$

The equilibrium row is then fully populated, since $[A^-] = x$ by the 1:1 stoichiometry and $[HA] = C - x$, so the constant follows with no solving:

$K_a = x^2 \div (C - x)$

The same route serves a weak base: pOH comes from the pH, giving x as:

$[OH^-] = 10^{-pOH}$

and the constant follows as:

$K_b = x^2 \div (C - x)$

Keep the $C - x$ denominator.

Conjugate Pairs Share One Product, Kw

For a conjugate pair, Ka and Kb are not independent. The two reactions add to the autoionization of water, so:

$K_a \times K_b = K_w = 1.0 \times 10^{-14}$ at 25 °C

© 2026 ExamFitter.com · Free AP Chemistry revision notes

$pK_a + pK_b = 14.00$

$pK_a = -\log K_a$

$pK_b = -\log K_b$

One constant buys the other: Kb of CH_3COO^- = $1.0 \times 10^{-14} \div 1.8 \times 10^{-5} = 5.6 \times 10^{-10}$, and Ka of NH_4^+ takes the same value. The relation holds only within a pair, HA with its own A^-, never between an acid and an unrelated base.

The seesaw follows: the stronger the acid, the weaker its conjugate base. Cl^-, from strong HCl, has no measurable basicity, while CH_3COO^- is weak but real:

$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$

That reaction actually runs. Salts inherit the pattern: a weak-acid anion gives a basic solution ($NaCH_3COO$, Na_2CO_3), a cation such as NH_4^+ an acidic one (NH_4Cl), and two strong-parent ions (NaCl, KNO_3) a neutral one.

Percent Ionization, Dilution and Comparing Acids

Percent ionization measures how far the equilibrium has run:

Percent ionization = $(x \div C) \times 100$ percent

Dilution shifts the ionization equilibrium right, so the percent ionized rises; but x itself falls. A diluted weak acid is more ionized and less acidic at once.

At fixed concentration, strength ties to a square root:

$[H_3O^+] \approx \sqrt{(K_a \times C)}$

A Ka 100 times larger gives $[H_3O^+]$ only 10 times larger and a pH about one unit lower, not two.

Worked Examples

Example 1: A weak acid pH where the approximation holds. For 0.50 mol L^{-1} CH_3COOH ($K_a = 1.8 \times 10^{-5}$), $x \approx \sqrt{(1.8 \times 10^{-5} \times 0.50)} = \sqrt{(9.0 \times 10^{-6})} = 3.0 \times 10^{-3}$ mol L^{-1}. Percent ionization = 0.60 percent, well inside the check. So $[H_3O^+] = 3.0 \times 10^{-3}$ mol L^{-1} and pH = $-\log(3.0 \times 10^{-3}) = 2.52$.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Example 2: A weak acid pH where the approximation fails. For 0.10 mol L^{-1} HF ($K_a = 6.8 \times 10^{-4}$), the approximation gives $x \approx \sqrt{(6.8 \times 10^{-5})} = 8.2 \times 10^{-3}$ mol L^{-1}: 8.2 percent ionized, so the check fails. The quadratic $x^2 + (6.8 \times 10^{-4})x - 6.8 \times 10^{-5} = 0$ gives $x = 7.9 \times 10^{-3}$ mol L^{-1}, so pH = 2.10 and the true percent ionization is 7.9 percent.

Example 3: Ka from a measured pH. A 0.50 mol L^{-1} solution of HA has pH 2.50. Then $x = [H_3O^+] = 10^{-2.50} = 3.16 \times 10^{-3}$ mol L^{-1}, $[A^-] = x$, and $[HA] = 0.50 - 0.00316$, so $K_a = (3.16 \times 10^{-3})^2 \div (0.50 - 0.00316) = 2.0 \times 10^{-5}$. Percent ionization is 0.63 percent.

Example 4: A weak base pH. For 0.20 mol L^{-1} NH_3 ($K_b = 1.8 \times 10^{-5}$), $x = [OH^-] \approx \sqrt{(1.8 \times 10^{-5} \times 0.20)} = \sqrt{(3.6 \times 10^{-6})} = 1.9 \times 10^{-3}$ mol L^{-1}, 0.95 percent ionized, so the approximation stands. Then $pOH = -\log(1.9 \times 10^{-3}) = 2.72$ and $pH = 14.00 - 2.72 = 11.28$.

Traps That Cost Marks in Topic 8.3

"0.10 M CH_3COOH has pH 1.00, the same as 0.10 M HCl." That is the strong-acid shortcut on a weak acid. Only 1.3 percent of the acetic acid ionizes: $[H_3O^+] = 1.3 \times 10^{-3}$ mol L^{-1} and pH 2.88.

"x is small, so write C − x as C and move on." Sometimes it is not small. For 0.10 mol L^{-1} HF the unchecked approximation gives pH 2.08, but the percent ionization is 8.2 percent, the check fails, and the quadratic gives pH 2.10.

"Diluting a weak acid lowers its percent ionization." The direction is the reverse: CH_3COOH is 1.3 percent ionized at 0.10 mol L^{-1} and 12.5 percent at 0.0010 mol L^{-1}. What falls is $[H_3O^+]$, from 1.3×10^{-3} to 1.3×10^{-4} mol L^{-1}, so the pH rises from 2.88 to 3.90 as the fraction climbs.

"Sodium acetate is a salt, so its solution is neutral." The cation is a spectator, but the anion is the conjugate base of a weak acid, $K_b = 5.6 \times 10^{-10}$, and a 0.010 mol L^{-1} solution has pH 8.37.

"Ka × Kb = Kw, so multiply any Ka by any Kb in the problem." Ka of CH_3COOH times Kb of NH_3 is $1.8 \times 10^{-5} \times 1.8 \times 10^{-5} = 3.2 \times 10^{-10}$, not Kw. The product equals Kw only for a conjugate pair: CH_3COOH with CH_3COO^-, NH_3 with NH_4^+.

"An acid with Ka 100 times larger gives 100 times the $[H_3O^+]$." At the same concentration, $[H_3O^+] \approx \sqrt{(K_a \times C)}$, so a factor of 100 in Ka becomes $\sqrt{100} = 10$ in $[H_3O^+]$ and about one pH unit.

© 2026 ExamFitter.com · Free AP Chemistry revision notes

Key Relationships to Remember

- $K_a = [H_3O^+][A^-] \div [HA]$
- $K_b = [BH^+][OH^-] \div [B]$; water appears in neither expression
- Small Ka or Kb means weak: the equilibrium lies left and most of the solute stays unionized
- The ICE table gives $K = x^2 \div (C - x)$, with x equal to $[H_3O^+]$ for an acid or $[OH^-]$ for a base
- $x \approx \sqrt{(K \times C)}$ is valid only at 5 percent ionization or below; otherwise solve the quadratic
- Percent ionization = $(x \div C) \times 100$ percent; it rises on dilution even though x itself falls
- A measured pH gives $x = 10^{-pH}$
- The constant follows from $K = x^2 \div (C - x)$ with no solving
- Conjugate pairs obey $K_a \times K_b = K_w$ and $pK_a + pK_b = 14.00$ at 25 °C; stronger acid means weaker conjugate base, and larger pKa means weaker acid
- Salts follow their ions: weak-acid anion, basic solution; weak-base cation, acidic solution; two strong parents, neutral

Continue Revising

Topic 8.3 Quiz: Weak Acid and Base Equilibria

Topic 8.3 Worksheet

Unit 8: All Topics

© 2026 ExamFitter.com · Free AP Chemistry revision notes