Acids, Bases & pH

Acid-base models, pH/pOH, conjugate pairs, strong vs weak, Ka/Kb, salt hydrolysis, and polyprotic acids.

01 Three models — REFERENCE

Model	Acid	Base
Arrhenius	makes H^+ in water	makes OH^- in water
Brønsted-Lowry	donates H^+	accepts H^+
Lewis	accepts an e^- pair	donates an e^- pair

02 pH, pOH, Kw — CORE RULE

$K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14}$ at 25 °C. $pH = -\log[H_3O^+]$, $pOH = -\log[OH^-]$, $pH + pOH = 14.00$. $[H^+] = 10^{\wedge}(-pH)$. pH 7 neutral, <7 acidic, >7 basic.

03 Conjugate pairs — CORE RULE

A conjugate pair differs by one H^+. In $HA + B \rightleftharpoons A^- + BH^+$: (HA, A^-) and (B, BH^+). Amphiprotic species (H_2O, HCO_3^-, $H_2PO_4^-$) act as acid or base depending on the partner.

04 Strong acids & bases — CORE RULE

Ionize completely. Strong acids: HCl, HBr, HI, HNO_3, $HClO_3$, $HClO_4$, H_2SO_4 (1st only). Strong bases: group 1 hydroxides; $Ca/Sr/Ba(OH)_2$ (2 OH^-). Monoprotic: $[H^+] = [HA]_0$. n-OH base: $[OH^-] = n[B]_0$.

05 Weak acid (Ka) — CORE RULE

$HA \rightleftharpoons H_3O^+ + A^-$, $K_a = [H_3O^+][A^-]/[HA]$. ICE gives $x^2/([HA]_0 - x) = K_a$. If $100 \cdot K_a < [HA]_0$, $x \approx \sqrt{(K_a \cdot [HA]_0)}$; $pH = -\log x$. Otherwise use the quadratic.

06 Weak base (Kb) — CORE RULE

$B + H_2O \rightleftharpoons BH^+ + OH^-$, $K_b = [BH^+][OH^-]/[B]$. ICE: $x^2/([B]_0 - x) = K_b$; if $100 \cdot K_b < [B]_0$, $x \approx \sqrt{(K_b \cdot [B]_0)}$; $[OH^-] = x$, $pOH = -\log x$, $pH = 14 - pOH$.

07 Ka · Kb = Kw — CORE RULE

For a conjugate pair: $K_a \cdot K_b = K_w = 1.0 \times 10^{-14}$, so $pK_a + pK_b = 14$. Stronger acid → weaker conjugate base. Get a salt anion's Kb = Kw/Ka, or a cation's Ka = Kw/Kb.

08 Salt hydrolysis — REFERENCE

Salt (from)	Solution
strong acid + strong base (NaCl)	neutral
strong acid + weak base (NH_4Cl)	acidic
weak acid + strong base ($NaCH_3COO$)	basic
weak acid + weak base	compare Ka vs Kb

09 Percent ionization — CORE RULE

% ionization = $(x / [HA]_0) \times 100$, x from the ICE table. Larger Ka → more ionized; more dilute → more ionized (Le Chatelier on dilution).

10 Polyprotic acids — CORE RULE

Stepwise: $K_{a1} \gg K_{a2} \gg K_{a3}$ (by ~10^4-10^5). When $K_{a1} \geq 20 \cdot K_{a2}$, treat as monoprotic for pH (K_{a1} ICE alone). Then $[X^{2-}] \approx K_{a2}$, independent of concentration. E.g. H_3PO_4: K_{a1} 7.5×10^{-3}, K_{a2} 6.2×10^{-8}, K_{a3} 4.8×10^{-13}.