

Chemical Equilibrium

K expressions, K_p/K_c, the reaction quotient, ICE tables, and Le Chatelier's principle.

01 Equilibrium constant

CORE RULE

$K_c = \frac{[\text{products}]^v}{[\text{reactants}]^v}$ (K_p uses partial pressures).
EXCLUDE pure solids and liquids. $N_2 + 3H_2 \rightleftharpoons 2NH_3$: $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$. For $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$: $K_p = P(CO_2)$.

02 K_p and K_c

CORE RULE

$K_p = K_c(RT)^{\Delta n}$, R = 0.0821, T in K, $\Delta n = (\text{mol gas products}) - (\text{mol gas reactants})$, counting gases only. $\Delta n = 0 \rightarrow K_p = K_c$.

03 Manipulating K

CORE RULE

Reverse a reaction $\rightarrow K_{\text{rev}} = 1/K$. Add reactions $\rightarrow K_{\text{net}} = K_1 \cdot K_2 \dots$. Scale all coefficients by x $\rightarrow K_{\text{scaled}} = K^x$. Convert moles to molarity (M = mol/V) before substituting.

04 Q vs K direction

CORE RULE

Q has K's form with current concentrations. $Q < K \rightarrow$ shifts right (toward products); $Q > K \rightarrow$ shifts left; $Q = K \rightarrow$ at equilibrium.

05 ICE table

METHOD

Initial / Change ($\pm vx$) / Equilibrium rows, then solve K for x. Three paths: perfect square (take $\sqrt{}$), x-small approximation (valid when $K < 10^{-3}$ or $[\text{init}] \gg x$; check $x < 5\%$), or the quadratic formula (keep the positive root). Always back-substitute to confirm K.

06 Decomposition from total P

METHOD

Given only total pressure + product ratio (e.g. $NH_4HS(s) \rightleftharpoons NH_3 + H_2S$, 1:1): write each partial pressure in one unknown, sum to the total, solve, then substitute into K_p.

07 Le Chatelier's principle

REFERENCE

Stress	Shift
add reactant / remove product	right
remove reactant / add product	left
$V \downarrow$ ($P \uparrow$), $\Delta n \neq 0$	toward fewer moles of gas
$V \uparrow$ ($P \downarrow$), $\Delta n \neq 0$	toward more moles of gas
$T \uparrow$, endothermic	right (K increases)
$T \uparrow$, exothermic	left (K decreases)
catalyst / inert gas at const V	no shift

08 Temperature is special

CORE RULE

Only temperature changes the value of K. Every other stress leaves K fixed and the system shifts to restore $Q = K$.

09 K magnitude $\rightarrow$ extent

CORE RULE

$K \gg 1$ ($> 10^3$): products dominate (essentially complete). $K \ll 1$ ($< 10^{-3}$): reactants dominate. $10^{-3} \leq K \leq 10^3$: comparable amounts of both. Rule-of-thumb thresholds for extent prediction.