Entropy & Free Energy

Entropy trends, ΔS°, ΔG°, spontaneity, the free-energy/K link, and crossover temperature.

01 Entropy trends — CORE RULE

More freedom → more entropy: S(gas) > S(liquid) > S(solid). Melting and vaporizing raise entropy.

02 Predicting the sign of ΔS — CORE RULE

Compare moles of gas on each side: more gas moles = higher entropy.

Dissolving a solid into ions raises entropy; precipitating lowers it.

03 ΔS° from standard entropies — CORE RULE

ΔS° = ΣS°(products) − ΣS°(reactants), each S° × its coefficient. (Standard molar entropies are tabulated and nonzero, even for elements.)

04 ΔG° from formation values — CORE RULE

ΔG° = ΣΔG°f(products) − ΣΔG°f(reactants). ΔG°f = 0 for an element in its standard state.

05 ΔG° = ΔH° − TΔS° — CORE RULE

When ΔG°f isn't available, use ΔG° = ΔH° − TΔS° (T in K). Watch units: ΔH° in kJ, ΔS° in J/K, so divide ΔS° by 1000 first.

06 Spontaneity — CORE RULE

ΔG° < 0 spontaneous; ΔG° > 0 nonspontaneous; ΔG° = 0 at equilibrium.

07 Free energy & K — CORE RULE

ΔG° = −RT ln K (T in K, R = 8.314 J/(mol·K)). K > 1 ↔ ΔG° < 0 (product-favored).

08 Non-standard ΔG — CORE RULE

ΔG = ΔG° + RT ln Q. ΔG < 0 → proceeds forward; ΔG > 0 → reverse; ΔG = 0 → at equilibrium.

09 Second law — CORE RULE

ΔS_univ = ΔS_sys + ΔS_surr, with ΔS_surr = −ΔH_sys/T (const T, P). Spontaneous ↔ ΔS_univ > 0.

10 Crossover temperature — CORE RULE

When ΔH° and ΔS° are both positive, the reaction turns spontaneous above T = ΔH°/ΔS° (where ΔG° changes sign).

11 Phase transitions — CORE RULE

At a boiling or freezing point the two phases are at equilibrium, so ΔG° = 0 and the transition temperature is T = ΔH°/ΔS° for that phase change.