

Gibbs Free Energy Cheat Sheet

Spontaneity, Hess's law, fuel-cell voltage, specific energy

ENGINEERING
CHEAT SHEET

Key equations

Quantity	Equation	Notes
Gibbs free energy	$G = U + pV - TS = H - TS$	Max reversible non-pV work at constant T, p
Change in G	$\Delta G = \Delta H - T \Delta S$	Constant temperature and pressure
Heat at constant T	$\Delta Q = T \Delta S$	Reversible heat exchange
Spontaneity	$\Delta G < 0$ spontaneous (exergonic); $\Delta G > 0$ non-spontaneous; $\Delta G = 0$ equilibrium	Says nothing about reaction rate
Hess's law	$\Delta H_{\text{rxn}} = \sum H_{\text{products}} - \sum H_{\text{reactants}}$	Path independent; same for ΔS
Reaction entropy	$\Delta S_{\text{rxn}} = \sum S_{\text{products}} - \sum S_{\text{reactants}}$	Products minus reactants rule
Cell voltage	$\Delta G = -n F E$	$F \approx 96,485 \text{ C/mol}$; n = electrons per reaction
Theoretical specific energy	$SE = (n F E / 3600) / M_{\text{reactants}}$ [Wh/kg]	1 mole basis, M in kg/mol

Key takeaways

- Enthalpy is internal energy plus pV: the total heat content at constant pressure. Entropy measures energy unavailable for work (disorder).
- Spontaneous does not mean fast: diamond turning into graphite is spontaneous but extremely slow.
- Hess's law lets you compute ΔH for reactions you cannot measure directly by adding known reactions. The article's graphite $\rightarrow$ CO $\rightarrow$ CO₂ example matches the direct value (−393.5 kJ) to within rounding.
- Worked example from the article: H₂ + ½O₂ $\rightarrow$ H₂O(l) at 298 K gives $\Delta H = -285.83 \text{ kJ}$, $\Delta S = -163.34 \text{ J/K}$, so $\Delta G \approx -237 \text{ kJ}$ (about 237 kJ of work available, 48.7 kJ rejected as heat).
- Fuel-cell and battery voltage follow from $\Delta G = -nFE$, so a larger $|\Delta G|$ per mole of electrons means a higher cell voltage.
- The article's LiCoO₂ example states n = 2 but its 107.2 Wh/mol corresponds to n = 1 at 4.0 V; check this before reusing it.

Theoretical specific energy (1 mol basis, from the article)

Chemistry	E (V)	Wh/mol	Reactant mass	Wh/kg
Ni-Fe	1.26	67.6	0.183 kg	369.9
Lead-acid	2.05	109.9	0.642 kg	171
LiCoO ₂ -C	4.0	107.2	0.170 kg	630.6