

5.8 Gibbs Energy & Spontaneity


$$\Delta G = \Delta H - T\Delta S$$

Why We Need Gibbs Energy

The Problem: The Second Law

$$\Delta S_{total} = \Delta S_{sys} + \Delta S_{surr} > 0$$

To determine if a reaction is spontaneous, we have to measure the entropy change of the entire universe (surroundings), which is highly impractical.

VS

The Solution: The Gibbs Criterion

We need a spontaneity criterion based solely on the system's properties.

Gibbs Energy allows us to predict spontaneity using only the system, assuming constant temperature (T) and pressure (p).

Defining the Gibbs Function

Anatomy of an Equation

$$G = H - TS$$

G (Gibbs Energy)

The net energy available to do useful work.

H (Enthalpy)

The total heat content or energy of the system.

TS (Temp × Entropy)

The energy that is unavailable to do work due to the chaotic motion and disorder of the system.

Like Enthalpy and Entropy, G is an extensive property and a thermodynamic state function.



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The Gibbs Change Equation (Constant T & p)

$$\Delta G_{\text{sys}} = \Delta H_{\text{sys}} - T\Delta S_{\text{sys}}$$

ΔH

The Heat Transfer
Component



$T\Delta S$

The Disorder
Component



Dimensional Analysis:
 $T\Delta S = (\text{K}) \times (\text{J/K}) = \text{J}$

Exam Note: Drop the “sys” subscript—it’s implied!
We simply write $\Delta G = \Delta H - T\Delta S$.

Spontaneity Rules & The Temperature Matrix

$\Delta G < 0 \rightarrow$ Spontaneous

$\Delta G > 0 \rightarrow$ Non-spontaneous

$\Delta G = 0 \rightarrow$ Equilibrium

		Entropy (ΔS)	
		Increase ($\Delta S +$)	Decrease ($\Delta S -$)
Enthalpy (ΔH)	Exothermic ($\Delta H -$)	$\Delta H -$ $\Delta S +$ Spontaneous at ALL temperatures	$\Delta H +$ $\Delta S +$ Spontaneous at HIGH temperatures
	Endothermic ($\Delta H +$)	$\Delta H -$ $\Delta S -$ Spontaneous at LOW temperatures	$\Delta H +$ $\Delta S -$ Non-spontaneous at ALL temperatures

Gibbs Energy & Equilibrium (K)

At a dynamic equilibrium state, the system's free energy is at its minimum, so $\Delta_r G = 0$. However, the Standard Gibbs Energy ($\Delta_r G^\circ$) tells us the extent of the reaction.

$$\Delta_r G^\circ = -RT \ln K \quad (\text{or } -2.303 RT \log K)$$

If $\Delta_r G^\circ < 0 \rightarrow K > 1$ (Products favored / Exothermic tendency)

If $\Delta_r G^\circ > 0 \rightarrow K < 1$ (Reactants favored / Endothermic tendency)

Summary: The Ultimate Criterion

The Math

$$\Delta G = \Delta H - T\Delta S$$

The Direction

$\Delta G < 0$ means
spontaneous at
constant T and p.

The Equilibrium

$\Delta_r G^\circ = -RT \ln K$
links energy to the
equilibrium constant.

Gibbs energy represents the net energy available to do useful work.



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