

Essential Question

What makes a process thermodynamically favored?

Standard State

- ΔG° = standard Gibbs free energy change
- $^\circ$ means everything is in its standard state

Gases: 1 atm

Solutions: 1 M

Solids and liquids: pure

The Sign of ΔG°

- ΔG° tells us if a process is thermodynamically favored

$$\Delta G^\circ < 0$$

thermodynamically
favored

$$\Delta G^\circ > 0$$

not favored

If $\Delta G^\circ > 0$, the reverse process is favored

Favored Does Not Mean Fast

- Old word: "spontaneous"
- Favored does not mean fast, sudden, or without cause

Iron rusts

$$\Delta G^\circ < 0$$

slow: years

Match burns

$$\Delta G^\circ < 0$$

fast: seconds

ΔG° from ΔG_f° Values

$$\Delta G^\circ_{\text{rxn}} = \Sigma \Delta G_f^\circ(\text{products}) - \Sigma \Delta G_f^\circ(\text{reactants})$$

Multiply each ΔG_f°
by its coefficient

Units: kJ/mol

ΔG_f° of an element
in its standard state = 0

e.g., $O_2(g)$, $Fe(s)$, $Br_2(l)$

Gibbs Free Energy and Thermodynamic Favorability

$$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

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$$\begin{array}{c} \Delta H^{\circ} \\ \text{kJ/mol}_{\text{rxn}} \end{array}$$

$$\begin{array}{c} T \\ \text{K} \end{array}$$

$$\begin{array}{c} \Delta S^{\circ} \\ \text{J}/(\text{mol}_{\text{rxn}} \cdot \text{K}) \end{array}$$

Convert ΔS° to kJ: divide by 1000

Gibbs Free Energy and Thermodynamic Favorability

Signs of ΔH° and ΔS°

ΔH°	ΔS°	$\Delta G^\circ < 0$ at
–	+	all T
+	–	no T
+	+	high T
–	–	low T

When ΔH° and ΔS° Compete

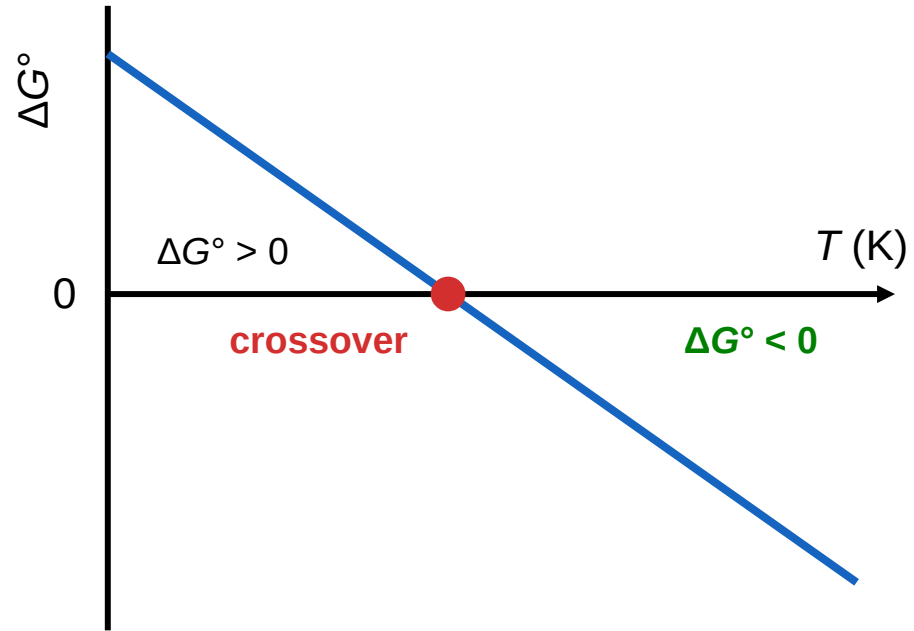
- Sometimes we need both ΔH° and ΔS° to decide

Process	ΔH°	ΔS°	Favored at
Freezing water	– helps	– hurts	low T (below 0 °C)
Dissolving NaNO_3	+ hurts	+ helps	high T (yes at 25 °C)

The Crossover Temperature

- At the crossover, $\Delta G^\circ = 0$
- Above or below it, the sign of ΔG° flips

$$T = \Delta H^\circ / \Delta S^\circ$$



$\Delta H^\circ > 0$ and $\Delta S^\circ > 0$

Example: ΔG° from ΔH° and ΔS°

Calculate ΔG° at 298 K for the reaction below. Is it thermodynamically favored?

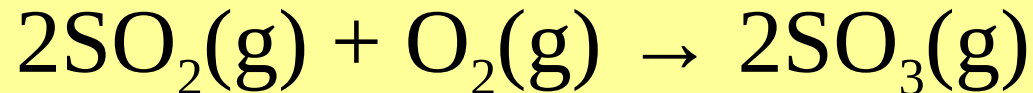


$$\Delta H^\circ = -92.2 \text{ kJ/mol}_{\text{rxn}}$$

$$\Delta S^\circ = -198.8 \text{ J/(mol}_{\text{rxn}} \cdot \text{K)}$$

Example: ΔG° from ΔG_f° Values

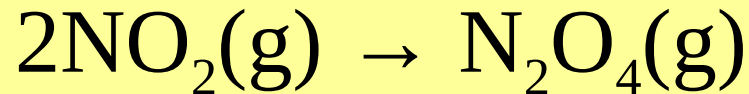
Calculate ΔG° for the reaction below using the data in the table.



Substance	ΔG_f° (kJ/mol)
$\text{SO}_2(\text{g})$	-300.2
$\text{SO}_3(\text{g})$	-371.1

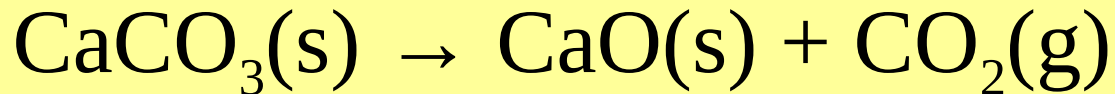
Example: Favored at Which Temperatures?

For this reaction, $\Delta H^\circ = -57.2 \text{ kJ/mol}_{\text{rxn}}$. Is it thermodynamically favored at all T, no T, high T, or low T? Justify your answer.



Example: Crossover Temperature

Above what temperature is the decomposition of CaCO_3 thermodynamically favored?



$$\Delta H^\circ = +178.3 \text{ kJ/mol}_{\text{rxn}}$$

$$\Delta S^\circ = +160.6 \text{ J/(mol}_{\text{rxn}} \cdot \text{K)}$$

Big Ideas

- $\Delta G^\circ < 0 \rightarrow$ thermodynamically favored
- $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ (convert J to kJ!)
- Signs of ΔH° and ΔS° predict which T
- Favored does not mean fast

$\Delta G^\circ < 0$
favored

$\Delta G^\circ > 0$
not favored