Exercise walk-through

Gibbs Free Energy and Thermodynamic Favorability ▪ 9.3

eXercise

You must be able to

- use $\Delta G = \Delta H - T\Delta S$
- interpret the sign of ΔG (favorable if < 0)
- find the temperature where a reaction becomes favorable

Method — The Gibbs equation

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

with T in **kelvin**. A reaction is **thermodynamically favorable** (spontaneous) when $\Delta G < 0$.

Method — The four cases

- $\Delta H < 0$, $\Delta S > 0$: **always** favorable ($\Delta G < 0$ at all T).
- $\Delta H > 0$, $\Delta S < 0$: **never** favorable.
- $\Delta H < 0$, $\Delta S < 0$: favorable at **low** T.
- $\Delta H > 0$, $\Delta S > 0$: favorable at **high** T.

Method — A worked ΔG

$\Delta H = -100$ kJ, $\Delta S = +50$ J/K $= 0.050$ kJ/K, $T = 300$ K:

$$\Delta G = -100 - 300(0.050) = -100 - 15 = -115 \text{ kJ (favorable)}.$$

Method — Crossover temperature

The reaction switches at $\Delta G = 0$: $T = \dfrac{\Delta H}{\Delta S}$. Watch **units** — convert ΔS to kJ/K to match ΔH.

Practice 2.1 ▪ 1 mark

Write the Gibbs free energy equation.

Solution 2.1

Method: The Gibbs equation

Worked steps

$\Delta G = \Delta H - T\Delta S$ B1.

Practice 2.2 ▪ 1 mark

A reaction has $\Delta G = -40$ kJ. Is it favorable?

Solution 2.2

Worked steps

Yes ($\Delta G < 0$) B1.

Practice 2.3 ▪ 2 marks

For $\Delta H = -50$ kJ, $\Delta S = +0.100$ kJ/K, $T = 300$ K, find ΔG.

Solution 2.3

Method: A worked ΔG

Worked steps

$\Delta G = -50 - 300(0.100) = -50 - 30 = -80$ kJ M1 A1.

Exam-style 3.1 ▪ 1 mark

A reaction is thermodynamically favorable when ΔG is

A positive

B negative

C zero

D equal to ΔH

Solution 3.1

Method: The Gibbs equation

A positive

B negative ✓

C zero

D equal to ΔH

Worked steps

B — negative.

Exam-style 3.2 ▪ 1 mark

A reaction has $\Delta H = +30$ kJ and $\Delta S = +0.10$ kJ/K.
(a) Is it favorable at low or high temperature?
(b) Find the temperature at which $\Delta G = 0$.

Solution 3.2

Worked steps

(a) High temperature (both positive) B1. (b) $T = \dfrac{\Delta H}{\Delta S} = \dfrac{30}{0.10} = 300$ K M1 M1 A1.

Exam-style 3.3 ▪ 2 marks

A reaction has $\Delta H < 0$ and $\Delta S < 0$. Explain at what temperatures it is favorable and why.

Solution 3.3

Method: The Gibbs equation

Worked steps

Favorable at **low** temperature — with $\Delta S < 0$, the $-T\Delta S$ term is positive and grows with T; only at low T is it small enough for the negative ΔH to dominate and keep $\Delta G < 0$ M1 A1.