Exercise walk-through

Gibbs free energy change, ΔG ▪ 23.4

eXercise

You must be able to

- state and use the Gibbs equation
- use the sign of ΔG to decide whether a reaction is feasible
- predict the effect of temperature on feasibility

Method — The Gibbs equation

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

A reaction is **feasible** when $\Delta G \leq 0$.
Watch the units: ΔH is in kJ mol ^{1} but ΔS is in J K ^{1} mol ^{1} — divide ΔS by 1000 (or multiply ΔH by 1000) before subtracting.
Example. ΔH = +178 kJ mol ^{1}, ΔS = +160 J K ^{1} mol ^{1}. At 298 K:
$\Delta G = 178 - 298(0.160) = 178 - 47.7 = +130$ kJ mol^{-1} (not feasible). It becomes feasible above $T = \Delta H/\Delta S = 178/0.160 = 1113$ K.

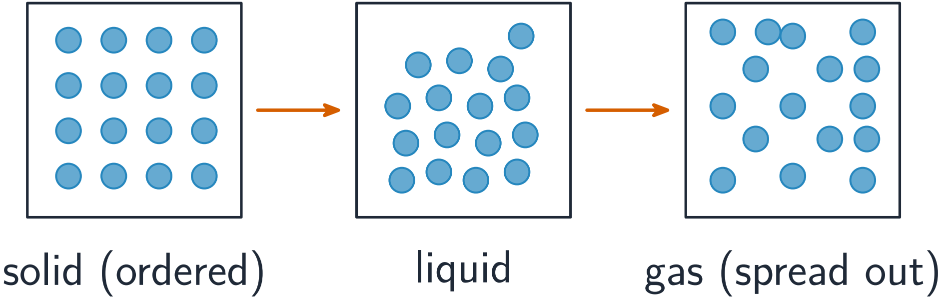
Method — The Gibbs equation

	ΔS **positive**	ΔS **negative**
ΔH **neg.**	feasible at **all** temperatures	feasible only at **low** tem-perature
ΔH **pos.**	feasible only at **high** tem-perature	**never** feasible

$\Delta G = \Delta H - T\Delta S$; **feasible when** $\Delta G \leq 0$

Method — The Gibbs equation

entropy increases: $\Delta S > 0$



Gibbs combines enthalpy and entropy changes

Practice 2.1 ▪ 1 mark

State the Gibbs equation.

Solution 2.1

Method: The Gibbs equation

Worked steps

$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ **B1**.

Practice 2.2 ▪ 1 mark

State the condition on ΔG for a reaction to be feasible.

Solution 2.2

Method: The Gibbs equation

Worked steps

$\Delta G \leq 0$ (negative or zero) **B1**.

Exam-style 3.1 ▪ 1 mark

A reaction has ΔH negative and ΔS positive. It is:

A feasible at all temperatures

B feasible only at high temperature

C feasible only at low temperature

D never feasible

Solution 3.1

Method: The Gibbs equation

A feasible at all temperatures ✓

B feasible only at high temperature

C feasible only at low temperature

D never feasible

Worked steps

A. With $-\Delta$H and $+\Delta$S, ΔG is negative at all temperatures.

Exam-style 3.2 ▪ 1 mark

In the Gibbs equation, the temperature T must be in:

A °C

B kelvin

C joules

D kJ

Solution 3.2

Method: The Gibbs equation

A °C

B kelvin ✓

C joules

D kJ

Worked steps

B. Temperature must be in kelvin.

Exam-style 3.3 ▪ 3 marks

A reaction has $\Delta H = +120$ kJ mol^{-1} and $\Delta S = +200$ J K^{-1}mol^{-1}.
(a) Calculate ΔG at 298 K and state whether the reaction is feasible.
(b) Calculate the minimum temperature at which the reaction becomes feasible.

Solution 3.3

Method: The Gibbs equation

Worked steps

(a) $\Delta G = 120 - 298(0.200)$ M1 $= 120 - 59.6 = +60.4$ kJ mol^{-1} A1; not feasible (positive ΔG) A1.

(b) feasible when $\Delta G = 0$: $T = \Delta H/\Delta S = 120/0.200 = 600$ K M1 A1.

Exam-style 3.4 ▪ 2 marks

Explain why an endothermic reaction with a positive entropy change becomes feasible only above a certain temperature.

Solution 3.4

Method: The Gibbs equation

Worked steps

at low T the $T\Delta S$ term is small, so $\Delta G = \Delta H - T\Delta S$ stays positive **M1**; raising T increases $T\Delta S$ until it exceeds ΔH, making ΔG negative and the reaction feasible **A1**.