

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 $\text{J K}^{-1} \text{mol}^{-1}$ — divide ΔS by 1000 (or multiply ΔH by 1000) before subtracting.

Example. $\Delta H = +178 \text{ kJ mol}^{-1}$, $\Delta S = +160 \text{ J K}^{-1} \text{mol}^{-1}$. At 298 K:
 $\Delta G = 178 - 298(0.160) = 178 - 47.7 = +130 \text{ kJ mol}^{-1}$ (not feasible). It becomes feasible above $T = \Delta H/\Delta S = 178/0.160 = 1113 \text{ K}$.

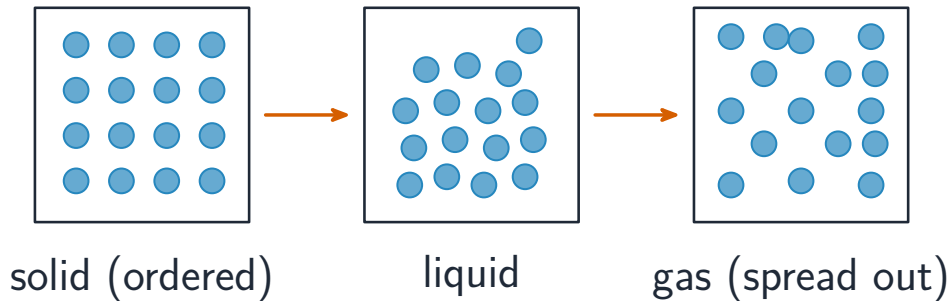
Method — The Gibbs equation

	ΔS positive	ΔS negative
ΔH neg.	feasible at all temperatures	feasible only at low temperature
ΔH pos.	feasible only at high temperature	never feasible

$$\Delta G = \Delta H - T\Delta S; \quad \text{feasible when } \Delta G \leq 0$$

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

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

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 $\Delta H = +120 \text{ kJ mol}^{-1}$ and $\Delta S = +200 \text{ J K}^{-1}\text{mol}^{-1}$.

- (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** $= 120 - 59.6 = +60.4 \text{ kJ mol}^{-1}$ **A1**; not feasible (positive ΔG) **A1**.

(b) feasible when $\Delta G = 0$: $T = \Delta H / \Delta S = 120 / 0.200 = 600 \text{ K}$ **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).