

Exercise walk-through

23.4

Gibbs free energy change, ΔG

A-Level Chemistry

Entropy ΔS

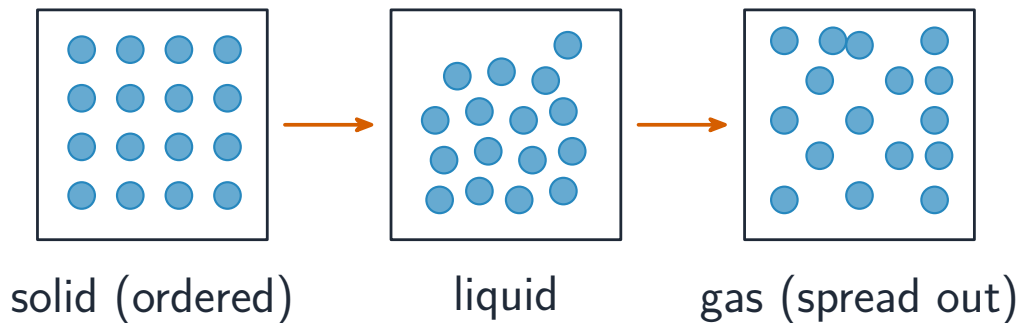
Entropy measures the number of arrangements (“disorder”).

■ solid $\rightarrow$ liquid $\rightarrow$ gas, dissolving: $\Delta S > 0$

■ more gas molecules: $\Delta S > 0$

$$\Delta S^{\ominus} = \sum S^{\ominus}_{\text{products}} - \sum S^{\ominus}_{\text{reactants}}$$

entropy increases: $\Delta S > 0$



Calculating entropy change, and feasibility

from standard entropies

$$\Delta S^{\ominus} = \sum S^{\ominus}(\text{products}) - \sum S^{\ominus}(\text{reactants})$$

the units

$\text{J K}^{-1}\text{mol}^{-1}$ – joules, while ΔH is in kilojoules

the sign

predict it first from the change in moles of gas

Gibbs free energy

$$\Delta G = \Delta H - T\Delta S, \text{ with } T \text{ in kelvin}$$

feasible

when $\Delta G \leq 0$

the feasibility temperature

set $\Delta G = 0$: $T = \frac{\Delta H}{\Delta S}$ – the temperature at which it becomes possible

Convert ΔS from joules to kilojoules before substituting. That factor of 1000 is the single commonest error in this whole topic.

Gibbs free energy ΔG

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

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

Gibbs free
energy :

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

A reaction is **feasible** when $\Delta G \leq 0$. Whether it is can depend on temperature.

ΔG : worked example

$$\Delta H = +120 \text{ kJ mol}^{-1}, \Delta S = +0.200 \text{ kJ K}^{-1} \text{ mol}^{-1}$$

$$\text{at } 298 \text{ K: } \Delta G = 120 - 298 \times 0.200 = +60 \text{ kJ mol}^{-1} \text{ (not yet feasible)}$$

$$\text{Set } \Delta G = 0: T = \frac{\Delta H}{\Delta S} = \frac{120}{0.200} = 600 \text{ K} - \text{feasible above } 600 \text{ K.}$$

Enthalpies of solution and hydration, continued



An instant cold pack feels cold because its salt dissolves endothermically (a positive ΔH_{sol}), driven by the rise in entropy

Exercises 2.1·3.1

2.1 State the Gibbs equation.

[1]

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

[1]

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

[1]

☐

A feasible at all temperatures

B feasible only at high temperature

C feasible only at low temperature

D never feasible

Exercises 2.1·3.1

2.1 State the Gibbs equation.

[1]

2.1

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

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

[1]

2.2

- $\Delta G \leq 0$ (negative or zero)

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

[1]

☐

A feasible at all temperatures

B feasible only at high temperature

C feasible only at low temperature

D never feasible

3.1 A

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

Exercise 3.2

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

[1]

☐

A °C

B kelvin

C joules

D kJ

Exercise 3.2

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

[1]

☐

A °C

B kelvin

C joules

D kJ

3.2 B

- Temperature must be in kelvin

Exercise 3.3 (a)

3.3 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.

[3]

Exercise 3.3 (a)

3.3 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. [3]

(a)

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

Exercise 3.3 (b)

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

(b) Calculate the minimum temperature at which the reaction becomes feasible. [2]

Exercise 3.3 (b)

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

(b) Calculate the minimum temperature at which the reaction becomes feasible. [2]

(b)

- feasible when $\Delta G = 0$: $T = \Delta H / \Delta S = 120 / 0.200 = 600 \text{ K}$

Exercise 3.4

3.4 Explain why an endothermic reaction with a positive entropy change becomes feasible only above a certain temperature. [2]

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3.4

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