Exercise walk-through

Entropy change, ΔS ▪ 23.3

eXercise

You must be able to

- define entropy as the number of ways the particles and energy can be arranged
- predict and explain the sign of ΔS for state changes and gas-number changes
- calculate ΔS from standard entropies

Method — Entropy and its sign

Entropy S = the number of possible arrangements of the particles and their energy. More disorder = higher entropy.

- $+\Delta$**S:** solid $\rightarrow$ liquid $\rightarrow$ gas; dissolving; more gas molecules formed; higher temperature.
- $-\Delta$**S:** the reverse (fewer gas molecules, freezing).

entropy increases: $\Delta S > 0$

solid (ordered) liquid gas (spread out)

Method — Entropy and its sign

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

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

Entropy feeds the Gibbs feasibility test

Method — Calculating ΔS

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

(units J $K^{-1}mol^{-1}$).

Practice 2.1 ▪ 1 mark

Define **entropy**.

Solution 2.1

Worked steps

the number of possible arrangements of the particles and their energy in a system B1.

Practice 2.2 ▪ 1 mark

State the sign of ΔS when a gas condenses to a liquid.

Solution 2.2

Method: Entropy and its sign

Worked steps

negative B1.

Exam-style 3.1 ▪ 1 mark

Which change has the **largest positive** entropy change?

A freezing of water

B $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

C $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

D condensing steam

Solution 3.1

A freezing of water

B $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ ✓

C $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

D condensing steam

Worked steps

B. A solid producing a gas gives the largest increase in entropy.

Exam-style 3.2 ▪ 1 mark

The entropy of a substance is **highest** when it is a:

A solid

B liquid

C gas

D crystal

Solution 3.2

A solid

B liquid

C gas ✓

D crystal

Worked steps

C. A gas has the highest entropy.

Exam-style 3.3 ▪ 3 marks

For $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, the standard entropies (J $K^{-1}mol^{-1}$) are: N 192, H 131, NH 193.

(a) Calculate $\Delta S^{\ominus}$ for the reaction.

(b) Explain the sign of your answer.

Solution 3.3

Method: Calculating ΔS

Worked steps

(a) $\Delta S^{\ominus} = \sum S(\text{products}) - \sum S(\text{reactants})$ M1; $= 2(193) - [192 + 3(131)]$ M1 $= 386 - 585 = -199$ J K^{-1}mol^{-1} A1.

(b) negative — 4 moles of gas become 2 moles, so the disorder decreases B1.

Exam-style 3.4 ▪ 2 marks

Explain why dissolving a solid in water usually has a positive entropy change.

Solution 3.4

Method: Entropy and its sign

Worked steps

the solid lattice breaks up and its ions/molecules spread out and mix among the water molecules M1, giving many more arrangements, so the entropy increases A1.