Exercise walk-through

Introduction to Entropy ▪ 9.1

eXercise

You must be able to

- describe **entropy** 熵 as the number of ways to arrange a system
- predict the **sign of** ΔS for a process
- rank states by entropy (gas $>$ liquid $>$ solid)

Method — What entropy is

Entropy (S) measures disorder — the number of ways energy and particles can be arranged. More spread-out, more random higher entropy.

Method — Entropy by state

For the same substance, $S_{\text{gas}} > S_{\text{liquid}} > S_{\text{solid}}$. Gases have far more ways to arrange their particles.

Method — Predicting the sign of ΔS

$\Delta S > 0$ (increase) when:

- a solid or liquid becomes a **gas**;
- the number of **gas molecules increases**;
- a solid **dissolves**.

$\Delta S < 0$ when the reverse happens (gas $\rightarrow$ liquid, fewer gas moles).

Method — A worked prediction

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$: 3 gas moles $\rightarrow$ 0 gas moles (a liquid), so $\Delta S < 0$ (a decrease).

Practice 2.1 ▪ 1 mark

Rank solid, liquid, and gas by entropy.

Solution 2.1

Method: Entropy by state

Worked steps

gas $>$ liquid $>$ solid **B1**.

Practice 2.2 ▪ 1 mark

State the sign of ΔS when a liquid boils.

Solution 2.2

Method: Predicting the sign of ΔS

Worked steps

Positive ($\Delta S > 0$) B1.

Practice 2.3 ▪ 1 mark

State the sign of ΔS for $2\mathrm{NO}_2(g) \rightarrow \mathrm{N}_2\mathrm{O}_4(g)$ (2 gas moles $\rightarrow$ 1).

Solution 2.3

Method: A worked prediction

Worked steps

Negative (fewer gas moles) B1.

Exam-style 3.1 ▪ 1 mark

Which process has $\Delta S > 0$?

A gas condensing to liquid

B water freezing

C a solid subliming to gas

D 2 gas moles forming 1 gas mole

Solution 3.1

A gas condensing to liquid

B water freezing

C a solid subliming to gas ✓

D 2 gas moles forming 1 gas mole

Worked steps

C — subliming a solid to gas greatly increases disorder.

Exam-style 3.2 ▪ 1 mark

Predict the sign of ΔS for each:
(a) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
(b) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
(c) dissolving salt in water

Solution 3.2

Method: A worked prediction

Worked steps

(a) positive (a gas is produced); (b) negative (4 gas moles $\rightarrow$ 2); (c) positive B1 B1 B1.

Exam-style 3.3 ▪ 2 marks

Explain, in terms of arrangements, why a gas has higher entropy than the same substance as a solid.

Solution 3.3

Method: Entropy by state

Worked steps

A gas has vastly more available positions and energy arrangements than a rigid, ordered solid, so far more microstates — hence higher entropy M1 A1.