

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

$2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(l)$: 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 $2\text{NO}_2(g) \rightarrow \text{N}_2\text{O}_4(g)$ (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

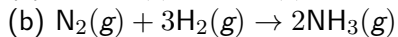
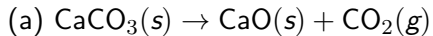


Worked steps

C — subliming a solid to gas greatly increases disorder.

Exam-style 3.2 ■ 1 mark

Predict the sign of ΔS for each:



(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**.