

# 9.1 Introduction to Entropy

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 9 marks

KEY WORDS entropy 熵

## Objective

Build the skills to answer exam questions on **entropy** — the measure of disorder.

You must be able to:

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

## 1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

### ■ What entropy is

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

### ■ 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.

### ■ Predicting the sign of $\Delta S$

 $\Delta S > 0$  (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).

### ■ 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).

## 2 Practice

Now apply the methods above.

2.1 Rank solid, liquid, and gas by entropy. [1]

2.2 State the sign of  $\Delta S$  when a liquid boils. [1]2.3 State the sign of  $\Delta S$  for  $2\text{NO}_2(g) \rightarrow \text{N}_2\text{O}_4(g)$  (2 gas moles  $\rightarrow$  1). [1]

## 3 Exam-style questions

3.1 Which process has  $\Delta S > 0$ ? [1]

- A** gas condensing to liquid
- B** water freezing
- C** a solid subliming to gas
- D** 2 gas moles forming 1 gas mole

3.2 Predict the sign of  $\Delta S$  for each:(a)  $\text{CaCO}_3(s) \rightarrow \text{CaO}(s) + \text{CO}_2(g)$  [1](b)  $\text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2\text{NH}_3(g)$  [1]

(c) dissolving salt in water [1]

**3.3** Explain, in terms of arrangements, why a gas has higher entropy than the same substance as a solid. [2]

## Solutions

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**2.1** gas > liquid > solid.

**2.2** Positive ( $\Delta S > 0$ ).

**2.3** Negative (fewer gas moles).

**3.1 C** — subliming a solid to gas greatly increases disorder.

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

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