

# 9 Entropy and free energy – Part 1

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

## Vocabulary

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*Write each word three times.***English****Write it 3 times** (English)

Entropy

Gibbs free energy

thermodynamically  
favorable

## Recall

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You already have a feel for these ideas:

- Gases are more “spread out” and disordered than solids.
- Some reactions happen on their own; others need pushing.
- You have met exothermic (heat out) and endothermic (heat in) reactions.

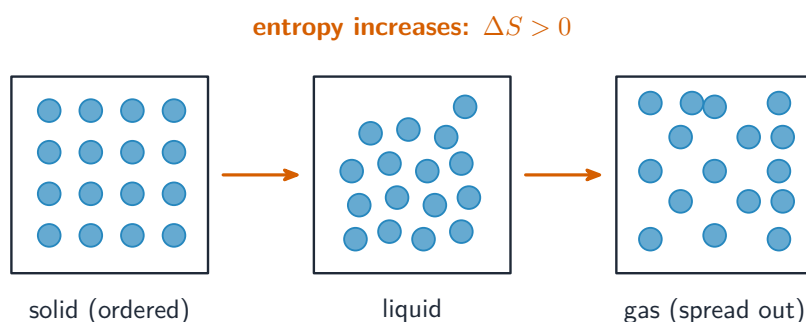
This sheet explains what decides whether a reaction happens by itself. Each idea has a worked example.

## New ideas

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### ■ 1 Entropy

**Entropy**  $S$  measures how spread-out and disordered a system is. It **increases** going solid  $\rightarrow$  liquid  $\rightarrow$  gas, when a solid dissolves, or when more gas is made.



## ■ 2 Gibbs free energy

Whether a reaction happens on its own depends on **Gibbs free energy**

:

$$\Delta G = \Delta H - T\Delta S.$$

A reaction is **thermodynamically favorable** (it can happen by itself) when  $\Delta G < 0$ .

|                 | $\Delta S$ positive                         | $\Delta S$ negative                        |
|-----------------|---------------------------------------------|--------------------------------------------|
| $\Delta H$ neg. | feasible at<br><b>all</b> temperatures      | feasible only at<br><b>low</b> temperature |
| $\Delta H$ pos. | feasible only at<br><b>high</b> temperature | never feasible                             |

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

## ■ 3 Enthalpy and entropy together

- Exothermic ( $\Delta H < 0$ ) **and** entropy-increasing ( $\Delta S > 0$ )  $\rightarrow$  always favorable.
- If they oppose each other, the **temperature** decides.

*Worked example.* A reaction with  $\Delta H = +40$  kJ and  $\Delta S = +0.120$  kJ/K becomes favorable only above  $T = \frac{\Delta H}{\Delta S} = \frac{40}{0.120} = 333$  K (about  $60^\circ\text{C}$ ).

## ■ 4 Favorable is not the same as fast

$\Delta G < 0$  means a reaction **can** happen, not that it happens **fast**. A favorable reaction can still be very slow if it has a high activation energy (diamond turning to graphite takes ages).

**Watch out:** match your units before using  $\Delta G = \Delta H - T\Delta S$  –  $\Delta H$  is usually in kJ but  $\Delta S$  in J, so convert one of them first.

## Practice

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Try these in order. The methods are all above.

**2.1** State whether entropy increases or decreases when a gas condenses into a liquid. [1]

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**2.2** State the condition on  $\Delta G$  for a reaction to be thermodynamically favorable. [1]

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**2.3** A reaction has  $\Delta H = -50$  kJ and  $\Delta S = +0.10$  kJ/K. State whether it is favorable, and why. [2]

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**2.4** A reaction has  $\Delta H = +30$  kJ and  $\Delta S = +0.10$  kJ/K. Find the temperature above which it becomes favorable. [3]

**2.5** Explain why a reaction can be thermodynamically favorable but still not happen at a noticeable rate. [2]

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