

Entropy, Gibbs energy and spontaneity

AP Chemistry · Test answers (mark scheme)

Each model answer is followed by a marking guide. Allow follow-through marks when a later step correctly uses an earlier wrong value, and accept answers within rounding.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 9

Question 1 Entropy basics (2 marks)

Entropy is a measure of the dispersal of energy and matter, or the number of microstates available. Its unit is **J/(mol·K)**. Evaporation has **positive** ΔS because a gas is more disordered than a liquid.

Marking: 1 mark for the definition and unit, 1 mark for the sign with reason.

Question 2 Entropy of a decomposition (3 marks)

$\Delta S^\circ = [2(82.6) + 3(205.1)] - 2(143.1) = [165.2 + 615.3] - 286.2 = \mathbf{+494.3 \text{ J/(mol·K)}}$.

Marking: 1 mark for the method, 1 for products sum, 1 for the final value.

Question 3 Gibbs calculation (3 marks)

a. $\Delta G = -120 - (298)(-0.250) = -120 + 74.5 = \mathbf{-45.5 \text{ kJ}}$, so spontaneous.

b. $T = \Delta H/\Delta S = -120 / -0.250 = \mathbf{480 \text{ K}}$.

Marking: (a) 1 mark for ΔG and 1 for the conclusion; (b) 1 mark.

Question 4 K from ΔG° (3 marks)

$\ln K = 15\,000 / (8.314 \times 298) = 6.054$. $K = \mathbf{426}$ (about 4.3×10^2). K is much greater than 1, so the equilibrium mixture contains mostly products.

Marking: 1 mark for $\ln K$, 1 for K , 1 for the interpretation.

Question 5 Sign combinations (2 marks)

$\Delta G = \Delta H - T\Delta S$. At low T the positive ΔH dominates, so ΔG is positive. As T increases the $-T\Delta S$ term becomes more negative and eventually outweighs ΔH , so **ΔG becomes negative** above $T = \Delta H/\Delta S$.

Marking: 1 mark for the low- T case, 1 for the high- T case.

Question 6 Reading a graph (3 marks)

- a. ΔH is the intercept at $T = 0$: **+60 kJ**.
- b. $\Delta G = 0$ at **300 K**.
- c. $\Delta S = \Delta H/T = 60 / 300 = 0.20 \text{ kJ}/(\text{mol}\cdot\text{K}) = \textbf{+200 J}/(\text{mol}\cdot\text{K})$.

Marking: 1 mark for each part.

Question 7 Non-standard conditions (2 marks)

$$\Delta G = \Delta G^\circ + RT \ln Q = -5000 + (8.314)(298)(\ln 50) = -5000 + 9692 = \textbf{+4692 J (+4.7 kJ)}.$$

ΔG is positive, so the **reverse** reaction proceeds (Q is above K).

Marking: 1 mark for ΔG , 1 for the direction.

Question 8 Comparing entropies (2 marks)

(a) **H₂O(g)**: gas particles have far more freedom. (b) **C₃H₈(g)**: the larger molecule has more ways to vibrate and rotate.

Marking: 1 mark for each part with reason.