

Entropy, Gibbs energy and reaction feasibility

Chemistry grades 11-12 (A Level · IB · Class 11-12) · Test answers (mark scheme)

Use these model answers and the marking notes to score yourself out of 20. Marks are given for consistent units and for the logic of setting $\Delta G = 0$ at the changeover, as well as for the numerical result.

Level: Chemistry grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB R1.4

Question 1 Meaning of entropy (2 marks)

In the liquid the particles are close together; in the gas they are far apart and move freely in all directions, so there are many more ways to arrange the particles and distribute energy. Entropy increases.

Marking: 1 mark for particles more free or further apart; 1 mark for more ways of arranging the energy.

Question 2 Predicting the sign of ΔS (3 marks)

- a. **Positive:** gas formed from solid.
- b. **Negative:** 2 mol of gas become 1 mol.
- c. **Negative:** ions in solution form a solid.

Marking: 1 mark each for the correct sign with a reason.

Question 3 Steam reforming: entropy (3 marks)

Products: $197.7 + 3 \times 130.7 = 589.8$. Reactants: $186.3 + 188.8 = 375.1$. $\Delta S^\circ = 589.8 - 375.1 = +214.7 \text{ J K}^{-1} \text{ mol}^{-1}$.

Marking: 1 mark for the sum of products; 1 mark for the sum of reactants; 1 mark for the answer with sign and unit.

Question 4 Steam reforming: feasibility (2 marks)

$\Delta G = 206 - 298 \times 0.2147 = 206 - 64.0 = +142 \text{ kJ/mol}$. ΔG is positive, so the reaction is **not spontaneous** at 298 K.

Marking: 1 mark for the calculation with ΔS in kJ; 1 mark for the conclusion.

Question 5 Steam reforming: temperature (3 marks)

At the changeover $\Delta G = 0$, so $T = \Delta H \div \Delta S = 206\,000 \div 214.7 = \mathbf{959 \text{ K}}$ (about 960 K).

Marking: 1 mark for $\Delta G = 0$; 1 mark for $T = \Delta H/\Delta S$ with consistent units; 1 mark for the

answer.

Question 6 Reading a ΔG -T graph (3 marks)

- a. ΔH is **negative** (ΔG is negative at $T = 0$) and ΔS is **negative** (ΔG rises as T increases).
- b. $\Delta G = 0$ at **400 K**.
- c. Spontaneous **below 400 K**.

Marking: 1 mark for each part.

Question 7 From ΔG to K (2 marks)

$$\ln K = 17\,000 \div (8.31 \times 298) = 6.865. K = e^{6.865} = \mathbf{9.6 \times 10^2}.$$

Marking: 1 mark for $\ln K$; 1 mark for K .

Question 8 Entropy of the surroundings (2 marks)

An exothermic reaction transfers heat to the surroundings, giving their particles more energy and more ways to arrange it. $\Delta S(\text{surroundings}) = -\Delta H/T$ is positive when ΔH is negative.

Marking: 1 mark for heat transferred to the surroundings; 1 mark for the link to $-\Delta H/T$ and a positive entropy change.