

Exercise walk-through

Free Energy and Equilibrium ■ 9.5

eXercise

You must be able to

- use $\Delta G^\circ = -RT \ln K$
- relate the sign of ΔG° to whether $K > 1$ or $K < 1$
- reason about the connection

Method — The link

$$\Delta G^\circ = -RT \ln K,$$

with $R = 8.314 \text{ J mol}^{-1}\text{K}^{-1}$ and T in kelvin. Free energy and the equilibrium constant carry the same information.

Method — Sign and K

- $\Delta G^\circ < 0$ $K > 1$ (products favored);
- $\Delta G^\circ > 0$ $K < 1$ (reactants favored);
- $\Delta G^\circ = 0$ $K = 1$.

Method — A worked value

If $K = 100$ at 298 K:

$$\Delta G^\circ = -(8.314)(298) \ln(100) = -(8.314)(298)(4.605) = -11\,400 \text{ J} = -11.4 \text{ kJ}.$$

Method — Reading the connection

A large positive ΔG° means a very small K (little product). The more negative ΔG° , the larger K and the further the equilibrium lies toward products.

Practice 2.1 ■ 1 mark

Write the equation linking ΔG° and K .

Solution 2.1

Worked steps

$$\Delta G^\circ = -RT \ln K \quad \text{B1}.$$

Practice 2.2 ■ 1 mark

If $\Delta G^\circ < 0$, is K greater or less than 1?

Solution 2.2

Worked steps

Greater than 1 **B1**.

Practice 2.3 ■ 1 mark

If $\Delta G^\circ = 0$, what is K ?

Solution 2.3

Worked steps

$$K = 1 \text{ (B1)}.$$

Exam-style 3.1 ■ 1 mark

A reaction with $K < 1$ has ΔG° that is

A negative

B positive

C zero

D equal to K

Solution 3.1

A negative

B positive 

C zero

D equal to K

Worked steps

B — positive.

Exam-style 3.2 ■ 1 mark

A reaction has $K = 1 \times 10^{-3}$ at 298 K.

- (a) State the sign of ΔG° .
- (b) Calculate ΔG° (use $R = 8.314$, $\ln(10^{-3}) = -6.9$).

Solution 3.2

Worked steps

(a) Positive **B1**. (b) $\Delta G^\circ = -(8.314)(298)(-6.9) = +17\,100 \text{ J} \approx +17 \text{ kJ}$
M1 M1 A1.

Exam-style 3.3 ■ 2 marks

Explain why a more negative ΔG° corresponds to a larger equilibrium constant.

Solution 3.3

Method: Reading the connection

Worked steps

$\Delta G^\circ = -RT \ln K$: a more negative ΔG° requires a larger $\ln K$, hence a larger K — the equilibrium lies further toward products **M1** **A1**.