

Exercise walk-through

9.3

Gibbs Free Energy and Thermodynamic Favorability

AP Chemistry

Free energy and equilibrium

Free energy connects to the equilibrium constant:

Standard and nonstandard

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

$$\Delta G = \Delta G^\circ + RT \ln Q$$

$\Delta G^\circ < 0 \Rightarrow K > 1$. At **equilibrium**, $\Delta G = 0$ and $Q = K$.

Coupled reactions

Add the ΔG° values. An unfavorable step (+20) coupled to -50:

$$+20 + (-50) = -30 \text{ kJ}$$

In cells, the “downhill” partner is ATP breakdown.

Exercises 2.1-2.3

2.1 Write the Gibbs free energy equation.

[1]

2.2 A reaction has $\Delta G = -40$ kJ. Is it favorable?

[1]

2.3 For $\Delta H = -50$ kJ, $\Delta S = +0.100$ kJ/K, $T = 300$ K, find ΔG .

[2]

Exercises 2.1·2.3

2.1 Write the Gibbs free energy equation.

[1]

2.1

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

2.2 A reaction has $\Delta G = -40$ kJ. Is it favorable?

[1]

2.2

- Yes ($\Delta G < 0$)
-

2.3 For $\Delta H = -50$ kJ, $\Delta S = +0.100$ kJ/K, $T = 300$ K, find ΔG .

[2]

2.3

- $\Delta G = -50 - 300(0.100) = -50 - 30 = -80$ kJ

Exercise 3.1

3.1 A reaction is thermodynamically favorable when ΔG is

[1]

☐

A positive

B negative

C zero

D equal to ΔH

Exercise 3.1

3.1 A reaction is thermodynamically favorable when ΔG is

[1]

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A positive

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D equal to ΔH

3.1 B

- negative

Exercise 3.2 (a)

3.2 A reaction has $\Delta H = +30 \text{ kJ}$ and $\Delta S = +0.10 \text{ kJ/K}$.

(a) Is it favorable at low or high temperature?

[1]

Exercise 3.2 (a)

3.2 A reaction has $\Delta H = +30 \text{ kJ}$ and $\Delta S = +0.10 \text{ kJ/K}$.

(a) Is it favorable at low or high temperature?

[1]

(a)

- High temperature (both positive)

Exercise 3.2 (b)

3.2 A reaction has $\Delta H = +30 \text{ kJ}$ and $\Delta S = +0.10 \text{ kJ/K}$.

(b) Find the temperature at which $\Delta G = 0$.

[3]

Exercise 3.2 (b)

3.2 A reaction has $\Delta H = +30$ kJ and $\Delta S = +0.10$ kJ/K.

(b) Find the temperature at which $\Delta G = 0$.

[3]

(b)

- $$T = \frac{\Delta H}{\Delta S} = \frac{30}{0.10} = 300 \text{ K}$$

Exercise 3.3

3.3 A reaction has $\Delta H < 0$ and $\Delta S < 0$. Explain at what temperatures it is favorable and why. [2]

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3.3

- Favorable at **low** temperature – with $\Delta S < 0$, the $-T\Delta S$ term is positive and grows with T ; only at low T is it small enough for the negative ΔH to dominate and keep $\Delta G < 0$