

Exercise walk-through

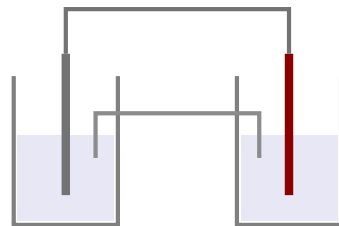
9.7

Coupled Reactions

AP Chemistry

What we will cover

- 1 Entropy
- 2 Gibbs free energy
- 3 Free energy and equilibrium
- 4 Coupled reactions
- 5 Galvanic and electrolytic cells
- 6 Cell potential and electrolysis



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.

Coupling, the Nernst shift, and electrolysis

coupled reactions

an unfavourable reaction ($\Delta G > 0$) can be driven by a favourable one ($\Delta G < 0$) **sharing a common intermediate**

the condition

the total ΔG of the pair must be negative – ATP hydrolysis is the biological case

the Nernst equation

away from standard conditions the cell potential shifts with concentration

qualitatively

as reactants are consumed and products build up, the potential **falls** toward zero – a dead battery is a cell at equilibrium

electrolysis

the **charge passed** determines how much substance is deposited – **Faraday's law**

the route

current $\times$ time $\rightarrow$ coulombs $\rightarrow$ moles of electrons $\rightarrow$ moles of substance $\rightarrow$ mass

A 2.0 A current for 30 minutes passes 3600 C, which is 0.0373 mol of electrons – and for Cu^{2+} that is **half** as many moles of copper.

Exercises 2.1-2.3

2.1 When two reactions are added, how do their ΔG values combine? [1]

2.2 Reaction A (+20 kJ) is coupled to B (−35 kJ). Find the total ΔG . [1]

2.3 Is the coupled reaction in 2.2 favorable? [1]

Exercises 2.1-2.3

2.1 When two reactions are added, how do their ΔG values combine? [1]

2.1

- They add
-

2.2 Reaction A (+20 kJ) is coupled to B (−35 kJ). Find the total ΔG . [1]

2.2

- $20 + (-35) = -15$ kJ
-

2.3 Is the coupled reaction in 2.2 favorable? [1]

2.3

- Yes ($\Delta G < 0$)

Exercise 3.1

3.1 An unfavorable reaction can be driven by coupling it to a reaction with [1]

☐

A a larger positive ΔG

B a sufficiently negative ΔG

C zero ΔG

D a higher activation energy

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☐

A a larger positive ΔG

B a sufficiently negative ΔG

C zero ΔG

D a higher activation energy

3.1 B

- a sufficiently negative ΔG to make the sum negative

Exercise 3.2 (a)

3.2 Reaction 1 ($\Delta G = +25 \text{ kJ}$) is coupled with reaction 2 ($\Delta G = -40 \text{ kJ}$).

(a) Find the total ΔG .

[2]

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[2]

(a)

- $25 + (-40) = -15 \text{ kJ}$

Exercise 3.2 (b)

3.2 Reaction 1 ($\Delta G = +25 \text{ kJ}$) is coupled with reaction 2 ($\Delta G = -40 \text{ kJ}$).

(b) State whether the coupled process is favorable.

[1]

Exercise 3.2 (b)

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(b) State whether the coupled process is favorable.

[1]

(b)

- Favorable ($\Delta G < 0$)

Exercise 3.3

3.3 Explain how cells use ATP hydrolysis to drive unfavorable reactions.

[2]

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3.3 Explain how cells use ATP hydrolysis to drive unfavorable reactions. [2]

3.3

- ATP hydrolysis is strongly favorable ($\Delta G \ll 0$); coupling it to an unfavorable reaction makes the combined ΔG negative, so the overall process proceeds