ANSWER KEY.

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9.7 Coupled Reactions

AP Chemistry | ANSWER KEY

Show your work with units. When reactions add, their ΔG° values add.

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1. Lead is made from lead(II) oxide by coupling two reactions:

(1) $PbO(s) \rightarrow Pb(s) + \frac{1}{2}O_2(g)$ $\quad \Delta G° = +187.9\ kJ/mol_{rxn}$

(2) $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$ $\quad \Delta G° = -257.2\ kJ/mol_{rxn}$

(a) Identify the common intermediate. (b) Write the overall reaction and find its ΔG°. (c) Is the overall reaction thermodynamically favored?

(a) **$O_2(g)$**: a product of (1) and a reactant in (2). It cancels.

(b) **$PbO(s) + CO(g) \rightarrow Pb(s) + CO_2(g)$**; $\Delta G° = (+187.9) + (-257.2) =$ **$-69.3\ kJ/mol_{rxn}$**

(c) **Yes**, $\Delta G° < 0$. The favored reaction (2) drives the unfavored reaction (1).

2. A student tries to make zinc at 25 °C by coupling $ZnO(s) \rightarrow Zn(s) + \frac{1}{2}O_2(g)$ ($\Delta G° = +318.3\ kJ/mol_{rxn}$) with $C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$ ($\Delta G° = -137.2\ kJ/mol_{rxn}$). Find ΔG° for the overall reaction. Does the coupling work at 25 °C?

$ZnO(s) + C(s) \rightarrow Zn(s) + CO(g)$; $\Delta G° = (+318.3) + (-137.2) =$ **$+181.1\ kJ/mol_{rxn}$**

No. ΔG° is still positive. The favored reaction is not negative enough to drive the unfavored one at 25 °C. (The overall reaction makes a gas, so $\Delta S° > 0$, and it becomes favored at high temperature.)

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3. In cells, glutamate + NH_3 → glutamine + H_2O has $\Delta G° = +14.2$ kJ/mol_{rxn}. It is coupled to ATP + H_2O → ADP + P_i ($\Delta G° = -30.5$ kJ/mol_{rxn}). Write the coupled reaction and find $\Delta G°$.

glutamate + NH_3 + ATP → glutamine + ADP + P_i (H_2O cancels)

$\Delta G° = (+14.2) + (-30.5) =$ **−16.3 kJ/mol_{rxn}, thermodynamically favored**

4. A reaction in a cell has $\Delta G° = +50.0$ kJ/mol_{rxn}. What is the smallest whole number of ATP molecules ($\Delta G° = -30.5$ kJ/mol_{rxn} each) that must react to make the coupled process thermodynamically favored? Show the total $\Delta G°$.

One ATP: 50.0 + (−30.5) = +19.5, still positive.

2 ATP: 50.0 + 2(−30.5) = **−11.0 kJ/mol_{rxn}**, favored.

5. A student says, “Coupling changes the $\Delta G°$ of the unfavored reaction so that it becomes negative.” Correct the statement. Then name one way, other than coupling, to drive a reaction with $\Delta G° > 0$.

The ΔG° of each reaction does not change. The two reactions add to one overall process, and the $\Delta G°$ values add. The overall $\Delta G°$ is negative.

Supply outside energy, such as electricity (electrolysis) or light (photosynthesis).

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