AP CHEMISTRY • EXERCISE SHEET

9.3 Gibbs Free Energy and Thermodynamic Favorability

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

Objective

Build the skills to answer exam questions on **Gibbs free energy** and thermodynamic favorability.

You must be able to:

- use $\Delta G = \Delta H - T\Delta S$
- interpret the sign of ΔG (favorable if < 0)
- find the temperature where a reaction becomes favorable

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

The Gibbs equation

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

with T in **kelvin**. A reaction is **thermodynamically favorable** (spontaneous) when $\Delta G < 0$.

The four cases

- $\Delta H < 0$, $\Delta S > 0$: **always** favorable ($\Delta G < 0$ at all T).
- $\Delta H > 0$, $\Delta S < 0$: **never** favorable.
- $\Delta H < 0$, $\Delta S < 0$: favorable at **low** T.
- $\Delta H > 0$, $\Delta S > 0$: favorable at **high** T.

A worked ΔG

$\Delta H = -100$ kJ, $\Delta S = +50$ J/K $= 0.050$ kJ/K, $T = 300$ K:

$$\Delta G = -100 - 300(0.050) = -100 - 15 = -115 \text{ kJ (favorable).}$$

Crossover temperature

The reaction switches at $\Delta G = 0$: $T = \dfrac{\Delta H}{\Delta S}$. Watch **units** —convert ΔS to kJ/K to match ΔH.

2 Practice

Now apply the methods above.

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]

3 Exam-style questions

3.1 A reaction is thermodynamically favorable when ΔG is [1]

- **A** positive
- **B** negative
- **C** zero
- **D** equal to ΔH

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

(a) Is it favorable at low or high temperature? [1]

(b) Find the temperature at which $\Delta G = 0$. [3]

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

and why. [2]

4 Go further

You are now ready for the real exam questions on this subtopic:

- work through the **9.3 Gibbs Free Energy and Thermodynamic Favorability** lesson on the **Learn** page;
- read the **Gibbs Free Energy and Thermodynamic Favorability** section of the AP Chemistry handout on the **Know** page.

Solutions

2.1 $\Delta G = \Delta H - T\Delta S$.

2.2 Yes ($\Delta G < 0$).

2.3 $\Delta G = -50 - 300(0.100) = -50 - 30 = -80$ kJ.

3.1 B —negative.

3.2 (a) High temperature (both positive). (b) $T = \dfrac{\Delta H}{\Delta S} = \dfrac{30}{0.10} = 300$ K.

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 $\Delta G < 0$.