The Second Law of Thermodynamics

Read from **Lesson 2 Part d:** [The Second Law of Thermodynamics] in the **Chemistry Tutorial** Section**, Chapter 17** of **The Physics Classroom.**

1. The Second Law of Thermodynamics

- **Spontaneous processes** are driven by the natural tendency for matter and energy to disperse.
- The **Second Law of Thermodynamics** states: *All spontaneous processes increase the entropy of the universe.*

2. System, Surroundings, and Universe

- **Universe = System + Surroundings**
- The Second Law applies to the entire universe, not just the system or surroundings individually.
- Entropy Rule: $\Delta S_{system} + \Delta S_{surroundings} > 0$.
  - **Example:** Freezing water.
  - $\Delta S_{system} < 0$ because water molecules become more ordered.
  - But $\Delta S_{surroundings} > 0$ because heat released increases randomness in surroundings.
  - Net effect: $\Delta S_{universe} > 0$, so freezing is spontaneous below 0°C.

3. Entropy Change of Surroundings

- Entropy change in the surroundings is driven by heat flow:
  - exothermic $\Delta H_{system} < 0$
  - endothermic $\Delta H_{system} > 0$
- Equation: $\Delta S_{surroundings} = - \Delta H_{system}/T$ The negative sign ensures consistency with the direction of heat flow.

Process Type	Heat Flow Direction	ΔH of System	T of Surroundings	$\Delta S_{surroundings}$
Exothermic	System to Surroundings	Negative	Increases	Positive (increases)
Endothermic	Surroundings to System	Positive	Decreases	Negative (decreases)

4. Temperature Effects

- The same heat flow has different effects depending on temperature:
  - At low T, entropy change of surroundings is large.
  - At high T, entropy change of surroundings is small.

5. Spontaneity and Entropy

ΔS_{system}	Matter Spread?	ΔH_{system}	Energy Spread?	Spontaneous?
+	Yes	- (exo)	Yes	Always
-	No	+ (endo)	No	Never
+	Yes	+ (endo)	No	Depends on T
-	No	- (exo)	Yes	Depends on T

Chemical Thermodynamics

Questions

1. Why does the condensation of water vapor decrease system entropy but still occur spontaneously?

2. How does the Second Law explain chemical or physical processes that appear to "create order"?

3. Explain why combustion reactions are typically spontaneous at all temperatures.

For Questions 4–5, consider these reactions:

Reaction	ΔH	ΔS
1	–	–
2	–	+
3	+	–
4	+	+

4. Which reaction(s) is/are spontaneous at all temperatures? Explain your reasoning.

5. Which reaction(s) will change spontaneity with changing temperature? Explain your reasoning.