Which Phase Transitions Result In A Decrease In The Entropy Of Their Surroundings? Select All That Apply.

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Understanding the thermodynamics of phase transitions is fundamental to grasping how energy and entropy change during various state changes of matter. One intriguing aspect of phase transitions is how they influence not only the system itself but also the entropy of their surroundings. Entropy, a measure of disorder or randomness in a system, often increases or decreases depending on the nature of the transition. This article aims to explore which phase transitions result in a decrease in the entropy of their surroundings, highlighting the principles behind these processes and providing detailed examples.

Fundamentals of Entropy and Phase Transitions

Before diving into specific phase transitions, it is essential to understand the basic thermodynamic concepts that underpin these phenomena.

What Is Entropy?

- Entropy (S) quantifies the degree of disorder in a system.
- It tends to increase spontaneously in isolated systems, aligning with the Second Law of Thermodynamics.
- Changes in entropy (ΔS) can be positive or negative depending on the process.

Phase Transitions and Their Impact on Entropy

- A phase transition involves a change in the state of matter, such as from solid to liquid or liquid to gas.
- These transitions usually involve energy exchange with the surroundings, termed latent heat.
- The change in entropy during a phase transition depends on the direction of the transition and the nature of the phases involved.

Types of Phase Transitions and Their Effect on Surroundings' Entropy

Phase transitions are broadly classified into:

- First-Order Transitions: Involve latent heat and discontinuous changes in enthalpy and entropy (e.g., melting, vaporization).
- Second-Order Transitions: Involve continuous changes without latent heat (e.g., ferromagnetic to paramagnetic transition).

This article focuses primarily on first-order transitions since they involve energy exchange with surroundings and can result in entropy changes in the environment.

Which Phase Transitions Result In A Decrease In The Entropy Of Their Surroundings?

The key question revolves around understanding the conditions under which the surroundings' entropy decreases during a phase transition. Since spontaneous processes tend to increase the total entropy of the universe, a process that decreases the surroundings' entropy must be compensated by a larger increase elsewhere or must be non-spontaneous under certain conditions.

Select all that apply:

- Condensation (Vapor to Liquid)
- Freezing (Liquid to Solid)
- Deposition (Gas to Solid)

Let's analyze each and understand why they may lead to a decrease in the surroundings' entropy.

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1. Condensation (Vapor to Liquid)

Description:
Condensation is the phase transition where a vapor turns into a liquid. This process releases latent heat into

the surroundings because molecules lose enough energy to transition into a more ordered liquid phase.

Entropy Considerations:
- The system’s entropy decreases because molecules become more ordered.
- The surroundings gain heat, which enhances their entropy.
- However, if the process occurs at constant temperature and pressure, the entropy of the surroundings increases due to the release of heat.

When does the surroundings’ entropy decrease?
- If heat is removed from the surroundings during condensation (e.g., in a cooling environment), then the surroundings’ entropy can decrease.
- But in typical spontaneous condensation at constant pressure, the surroundings’ entropy increases because heat is released into them.

Conclusion:
- Under standard conditions, condensation results in an increase in the surroundings’ entropy.
- However, if heat is extracted from the surroundings during condensation (implying cooling), the surroundings’ entropy decreases, making this process a candidate for the answer.

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2. Freezing (Liquid to Solid)

Description:
Freezing involves the transition of a liquid into a solid. It releases latent heat into the surroundings, leading to an increase in the surroundings’ entropy if the heat remains within the system.

Entropy Considerations:
- The system’s entropy decreases because the molecules become more ordered.
- The surroundings absorb heat, increasing their entropy.

When does the surroundings’ entropy decrease?
- If the process occurs with heat removal from the surroundings (e.g., freezing in a refrigeration cycle), the surroundings lose heat and their entropy decreases.
- This is common in refrigeration and natural freezing conditions where heat is taken away from the environment.

Conclusion:
- Freezing can result in a decrease in the surroundings’ entropy when heat is extracted from the environment during the process.

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3. Deposition (Gas to Solid)

Description:
Deposition is the phase transition where a gas transforms directly into a solid, bypassing the liquid phase (e.g., frost formation).

Entropy Considerations:
- The system's entropy decreases significantly because gas molecules become highly ordered as they form a solid.
- The process releases latent heat, which, if transferred to the surroundings, increases their entropy.

When does the surroundings' entropy decrease?
- If heat is removed from the surroundings during deposition (for example, frost forming on a cold surface), then the surroundings' entropy decreases because they are losing heat.

Conclusion:
- Deposition can lead to a decrease in the surroundings' entropy when the environment is cooled by removing heat during the process.

Summary of Phase Transitions Resulting in Decrease of Surroundings' Entropy

Phase Transition	Typical Effect on Surroundings' Entropy	Conditions for Decrease in Surroundings' Entropy
Condensation	Usually increases, but can decrease if heat is removed	When heat is extracted during condensation (e.g., in a cooled environment)
Freezing	Usually increases, but can decrease if heat is removed	When heat is removed from the surroundings during freezing
Deposition	Usually increases, but can decrease if heat is removed	When heat is removed during frost formation or deposition

Key Takeaway:
Phase transitions like freezing, condensation, and deposition tend to increase the surroundings' entropy when they release heat into the environment. However, if these processes occur under conditions where heat is extracted from the surroundings (e.g., during cooling or in refrigeration), they can result in a decrease in the surroundings' entropy.

Practical Examples and Applications

Understanding these principles is crucial in various practical applications:

- Refrigeration and Air Conditioning:
Freezing water in a refrigerator removes heat from the surroundings, decreasing the surroundings' entropy locally. This process relies on the transfer of heat from the interior (system) to the external environment.

- Cryogenics and Cold Storage:
Deposition and freezing are used to achieve ultra-low temperatures, effectively decreasing the entropy of the surroundings by removing heat.

- Weather Phenomena:
Frost formation (deposition) on cold surfaces results in local decreases in environmental entropy as heat is conducted away.

- Industrial Processes:
Controlled condensation and freezing are used in manufacturing to manipulate entropy and energy flow efficiently.

Conclusion

In thermodynamics, phase transitions can influence the entropy of their surroundings significantly. The key to whether a transition results in a decrease in the surroundings' entropy lies in the direction of heat flow:

- When heat is removed from the surroundings during a phase transition, the surroundings' entropy decreases.
- Conversely, when heat is released into the surroundings, their entropy typically increases.

The phase transitions that can result in a decrease in the surroundings' entropy include:

- Freezing (liquid to solid) — when heat is extracted.
- Deposition (gas to solid) — when heat is removed.

Condensation generally increases the surroundings' entropy unless conducted under specific cooling conditions.

Understanding these principles provides insight into natural and engineered processes involving heat transfer and phase changes, emphasizing the importance of the thermodynamic context in predicting entropy changes.

References & Further Reading

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Note: This comprehensive overview aims to clarify the conditions under which phase transitions lead to a decrease in the entropy of their surroundings, supporting better understanding of thermodynamic principles in real-world applications.

Frequently Asked Questions

Which phase transitions result in a decrease in the entropy of their surroundings? Select all that apply.

Freezing of water, Condensation of vapor, Deposition of gas to solid

Does freezing water increase or decrease the entropy of the surroundings?

It decreases the entropy of the surroundings.

When water vapor condenses into liquid, what happens to the entropy of the surroundings?

It decreases.

Which of the following phase transitions involve a decrease in the entropy of the surroundings? (Select all that apply)

Deposition (gas to solid), Freezing (liquid to solid), Condensation (vapor to liquid)

Why do phase transitions like freezing and condensation decrease the entropy of their surroundings?

Because they release heat into the surroundings, which results in local decreases in entropy despite the overall entropy increase in the universe.

Is melting ice an example of a phase transition that decreases the entropy of the surroundings?

No, melting ice increases the entropy of the surroundings.

Which phase change directly results in a decrease in the entropy of the surroundings?

Deposition (gas to solid)

Does the sublimation of dry ice increase or decrease the entropy of the surroundings?

It increases the entropy of the surroundings.

Select all phase transitions that involve a decrease in the surroundings' entropy:

Freezing, Condensation, Deposition

How does the heat exchange during freezing or condensation affect the entropy of the surroundings?

It causes a decrease in the surroundings' entropy because heat is released to the surroundings.

Additional Resources

Phase Transitions and Surrounding Entropy: An Expert Overview

Understanding the thermodynamics of phase transitions is fundamental to numerous scientific and engineering fields, from materials science to atmospheric physics. Among the key concepts in this domain is entropy, a measure of disorder or randomness in a system. When a phase transition occurs, it often influences the entropy of both the system and its surroundings. A particularly intriguing aspect is identifying which phase transitions result in a decrease in the entropy of their surroundings. This article aims to clarify this concept comprehensively, examining the types of phase transitions involved and the thermodynamic principles that govern these changes.

Foundational Concepts: Entropy and Phase Transitions

Before delving into specific phase transitions, it's essential to understand the underlying principles.

What is Entropy?

Entropy (denoted as S) quantifies the degree of disorder or the number of microscopic configurations that correspond to a thermodynamic system's macroscopic state. According to the second law of thermodynamics, the total entropy of an isolated system tends to increase over time, favoring spontaneous processes.

What is a Phase Transition?

A phase transition refers to a transformation of a substance from one phase to another, such as from solid to liquid (melting), liquid to gas (vaporization), or between different crystalline structures (allotropes). These transitions involve a change in the system's internal energy, structure, and entropy.

Types of Phase Transitions and Their Entropy Signatures

Phase transitions are broadly classified into two categories based on their thermodynamic characteristics:

- First-order transitions: These involve a discontinuous change in entropy and enthalpy. Examples include

melting, vaporization, and sublimation.
- Second-order transitions: These involve continuous changes with no latent heat, such as the transition in ferromagnetic materials at the Curie point.

This classification is crucial because the impact on surroundings' entropy varies significantly depending on the type.

Which Phase Transitions Result In a Decrease in Surroundings' Entropy?

The core question revolves around identifying specific phase transitions that lead to a decrease in the entropy of their surroundings. To address this, it's essential to analyze the thermodynamic process, the nature of the transition, and how heat exchange occurs.

General Thermodynamic Principles

In any spontaneous process, the total entropy (system + surroundings) must increase, or remain constant in ideal reversible processes. When a phase transition occurs within a system, the environment's entropy change depends on the heat exchanged and the temperature at which the process occurs.

The change in surroundings' entropy ($\Delta S_{surroundings}$) associated with heat exchange (Q) at temperature T is:

$$
\Delta S_{surroundings} = -\frac{Q}{T}
$$

- If Q is positive (heat flows into the surroundings): $\Delta S_{surroundings}$ is negative, decreasing the surroundings' entropy.
- If Q is negative (heat flows out): $\Delta S_{surroundings}$ is positive, increasing the surroundings' entropy.

Therefore, phase transitions involving heat flow out of the surroundings can lead to a decrease in their entropy.

Specific Phase Transitions That Decrease Surroundings' Entropy

Based on thermodynamic principles and typical process energetics, certain phase transitions are more likely to result in a decrease in the surroundings' entropy.

1. Condensation of a Gas into a Liquid

Description:
When a vapor condenses into a liquid, the system releases latent heat into the surroundings. This heat release occurs because the transition from a higher-entropy phase (gas) to a lower-entropy phase (liquid) involves a decrease in the system's entropy.

Thermodynamics:
- Heat exchange: During condensation, Q (latent heat) is released to the surroundings.
- Impact on surroundings: The surroundings absorb this heat, which increases their entropy.
- Net effect: Since the surroundings gain heat, their entropy increases, and the process, in total, aligns with the second law.

But, if the environment is at a temperature lower than the condensation temperature, the heat flow from the system to the surroundings can be such that the surroundings' entropy increase is less than the entropy decrease within the system, leading to an overall entropy increase, but from the perspective of the surroundings alone, their entropy increases—not decreases.

Conclusion:
Condensation generally results in an increase in the surroundings' entropy. Therefore, it does not fulfill the criteria of decreasing their entropy.

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2. Freezing of a Liquid (Solidification)

Description:
When a liquid freezes into a solid, the system releases latent heat into its surroundings.

Thermodynamics:
- Similar to condensation, heat is expelled.
- The surroundings absorb heat, leading to an increase in their entropy.

Net effect:

Again, the surroundings' entropy increases during freezing. Hence, freezing does not decrease the entropy of the surroundings.

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3. Sublimation from Solid to Gas (Via Deposition or Sublimation)

Description:
Sublimation involves direct transition from solid to gas or vice versa. When a gas condenses directly onto a solid surface (deposition), the process releases heat.

Implication:
- During deposition, heat is released into the surroundings, increasing their entropy.
- During sublimation, heat absorption occurs, with the surroundings losing heat, decreasing their entropy.

Summary:
- Deposition (gas to solid): releases heat → increases surroundings' entropy.
- Sublimation (solid to gas): absorbs heat → decreases surroundings' entropy.

Therefore, sublimation can potentially result in a decrease in the surroundings' entropy if heat is absorbed from the surroundings, but the key is the direction of heat flow.

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4. Melting of a Solid (Fusion)

Description:
Melting involves the transition from solid to liquid, which requires heat input from the surroundings.

Implication:
- Energy is absorbed during melting.
- The surroundings lose heat, leading to a decrease in their entropy.

Conclusion:
- When melting occurs at constant temperature, the surroundings typically lose heat, decreasing their entropy.

However, the overall entropy change of the universe still increases because the entropy of the system increases significantly.

Summary Table of Key Phase Transitions and Surroundings' Entropy Effects

Phase Transition	Heat Flow Direction	Effect on Surroundings' Entropy	Can It Decrease Surroundings' Entropy?
Condensation of vapor	Into surroundings	Increases	No
Freezing of liquid	Into surroundings	Increases	No
Melting of solid	From surroundings	Decreases	Yes
Sublimation (solid to gas)	From surroundings (sublimation)	Decreases if heat absorbed	Yes
Deposition (gas to solid)	Into surroundings	Increases	No

Additional Considerations: Reversibility and Thermodynamic Context

The above analysis assumes idealized, often reversible processes. In real-world scenarios, processes are often irreversible, and entropy changes are more complex.

- Reversible processes: The surroundings' entropy change can be minimized, but not negative if the total entropy of universe increases.
- Irreversible processes: Entropy production within the system may overshadow the entropy decrease in surroundings, making such decreases less practically observable.

Conclusion: Which Phase Transitions Result In a Decrease In The Entropy Of Their Surroundings?

Based on thermodynamic principles and typical phase transition energetics, the key phase transitions that can result in a decrease in the surroundings' entropy are:

- Melting of a solid (fusion): Because heat is absorbed from the surroundings, causing their entropy to decrease.
- Sublimation (solid to gas): Specifically during sublimation when heat is taken from surroundings, leading to a reduction in their entropy.

In contrast, phase transitions like condensation, freezing, or deposition tend to increase the surroundings' entropy because heat flows into the surroundings, raising their entropy.

Final Remarks

Understanding the conditions under which phase transitions impact the entropy of surroundings is vital for designing thermodynamic cycles, controlling material processes, and explaining natural phenomena. Recognizing that heat flow direction and the nature of the transition determine whether the surroundings' entropy increases or decreases enables scientists and engineers to predict and manipulate these processes effectively.

In essence, the phase transitions that involve absorbing heat from the surroundings (e.g., melting, sublimation) have the potential to decrease the entropy of their surroundings under specific thermodynamic conditions. Conversely, those that release heat into the surroundings (e.g., condensation, freezing) tend to increase their entropy.

Disclaimer: This analysis assumes standard conditions and idealized processes. Real-world systems may involve additional complexities, including irreversibility, kinetic barriers, and environmental constraints.

[Which Phase Transitions Result In A Decrease In The Entropy Of Their Surroundings Select All That Apply]

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