

For One Mole Of Substance At A Given Temperature, Select The Member In Each Pair With The Higher Entropy.

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Understanding entropy and its implications in thermodynamics is fundamental for students and professionals working in chemistry, physics, and related fields. Entropy, a measure of disorder or randomness in a system, plays a crucial role in determining the spontaneity of processes, the direction of chemical reactions, and the equilibrium state of systems. When comparing different states, phases, or configurations of a substance, selecting the one with higher entropy often provides insight into the system's stability and behavior.

This article delves into the concept of entropy, its significance in thermodynamics, and how to determine which member in each pair of states possesses higher entropy for one mole of a substance at a given temperature. We will explore practical examples, theoretical foundations, and the principles guiding these selections to equip you with a comprehensive understanding.

Understanding Entropy: The Foundation of Thermodynamics

What Is Entropy?

Entropy (denoted as S) is a thermodynamic property that quantifies the degree of disorder or randomness in a system. It reflects the number of microscopic configurations (microstates) corresponding to a macroscopic state. The higher the number of microstates, the greater the entropy.

Mathematically, entropy is related to the number of microstates (Ω) by Boltzmann's equation:

$$S = k_B \ln \Omega$$

where:

- S is the entropy,
- k_B is Boltzmann's constant,
- Ω is the number of microstates.

For macroscopic systems, the change in entropy can be calculated using thermodynamic relationships, especially when transitioning between different states.

Significance of Entropy in Thermodynamics

Entropy influences various thermodynamic processes:

- Spontaneity: Processes tend to proceed spontaneously in the direction of

increasing entropy, aligning with the Second Law of Thermodynamics.

- Equilibrium: Systems reach equilibrium when their entropy is maximized under given constraints.
- Phase Changes: Transitions between phases involve entropy changes, such as melting or vaporization.
- Chemical Reactions: The change in entropy helps determine the feasibility and extent of reactions.

Comparing Entropy in Different States of a Substance

When analyzing different states or configurations of a substance, the primary task is to determine which state has higher entropy. At a fixed temperature, the state with higher entropy is generally more disordered and thermodynamically favored under given conditions.

Key Factors Affecting Entropy

- Phase of the Substance: Gases have higher entropy than liquids, which in turn have higher entropy than solids, due to greater molecular freedom.
- Temperature: Increasing temperature generally increases entropy because molecules gain energy and explore more microstates.
- Molecular Complexity: More complex molecules tend to have higher entropy because of more possible configurations.
- Volume and Pressure: Expanding a gas (increasing volume at constant temperature) increases entropy.

Principles for Selecting the Member with Higher Entropy

Given two states or configurations of a substance at the same temperature, the one with higher entropy is typically the more disordered or energetic state. Here are fundamental principles and guidelines to assist in making such selections:

1. Phase Considerations

- Gaseous states have higher entropy than liquids and solids.
- Transitioning from solid to liquid (melting) increases entropy.
- Transitioning from liquid to gas (vaporization) increases entropy further.

2. Effect of Temperature

- Higher temperature correlates with higher entropy.
- For two states at different temperatures, the one at the higher temperature generally has higher entropy, assuming similar phases.

3. Microstate Counting and Molecular Complexity

- More complex or larger molecules have higher entropy due to more microstates.
- Structural isomers with more degrees of freedom tend to have higher entropy.

4. Volume and Pressure Changes

- Expanding a gas at constant temperature increases entropy.
- Compressing a gas decreases entropy.

5. Thermodynamic Calculations

- Use standard entropy tables and thermodynamic equations to quantify entropy differences.
- For phase changes, standard molar entropy values are available in tables.

Practical Examples of Selecting the Member with Higher Entropy

Let's examine specific pairs of states or configurations and determine which has higher entropy.

Example 1: Solid Ice vs. Liquid Water at 0°C

- At 0°C, solid ice and liquid water coexist in equilibrium.
- The entropy of liquid water is higher than that of ice due to increased molecular disorder.
- Selection: Liquid water has higher entropy.

Example 2: Vaporized vs. Liquefied Substance at the Same Temperature

- Vapor (gas) has higher entropy than the liquid phase.
- Selection: Vaporized form has higher entropy.

Example 3: Two Isomers with Different Structural Complexity

- Isomer A has a more branched structure, while Isomer B is linear.
- The more branched isomer generally has higher entropy because of increased microstates.
- Selection: The more branched isomer.

Example 4: Comparing Two Gases at Equal Temperature and Pressure

- Gas A has a molar mass of 16 g/mol (methane), and Gas B has a molar mass of 44 g/mol (methanol vapor).
- The lighter gas (methane) typically has higher entropy because of higher molecular velocity and microstates.
- Selection: Methane vapor has higher entropy.

Role of Standard Entropy Values and Thermodynamic Data

Standard molar entropy (S°) values provide a quantitative basis for comparing the entropy of different substances or states. These values are tabulated at standard conditions (usually 1 bar, 25°C) and are invaluable for calculations involving entropy changes.

Using Standard Entropy Data:

- Refer to thermodynamic tables for S° values.
- Calculate the difference in entropy (ΔS) for phase changes or reactions.
- For a pair of states, compare their S° values directly.

Example Calculation:

Suppose you are comparing the entropy of water in two states:

- Ice at 0°C: $S^\circ_{\text{ice}} \approx 24.2$ J/(mol·K)
- Water vapor at 100°C: $S^\circ_{\text{gas}} \approx 188.8$ J/(mol·K)

Since $188.8 > 24.2$, vapor has higher entropy than ice.

Implications in Thermodynamic Processes

The principle of selecting the member with higher entropy has broad implications:

- Spontaneous Processes: Tend to occur in the direction that increases the total entropy of the system and surroundings.
- Phase Transitions: Proceed from lower to higher entropy states.
- Chemical Reactions: Favor pathways that lead to an increase in entropy, especially at constant temperature and pressure.

Conclusion

In thermodynamics, the comparison of entropy between different states or configurations of a substance at a given temperature is essential for

understanding process spontaneity, stability, and equilibrium. When selecting the member in each pair with higher entropy, consider phase differences, temperature, molecular complexity, and thermodynamic data.

Key takeaways include:

- Gaseous states generally have higher entropy than liquids and solids.
- Increasing temperature increases entropy.
- Molecular structure influences entropy.
- Volume expansion increases entropy.

By applying these principles and utilizing standard entropy data, scientists and engineers can accurately determine which state has higher entropy, thereby predicting the thermodynamic favorability of various processes. Mastery of these concepts is fundamental to advancing in fields such as physical chemistry, chemical engineering, and thermodynamics.

Keywords for SEO Optimization:

- Entropy comparison
- Thermodynamics principles
- Standard molar entropy
- Phase changes and entropy
- Spontaneous processes
- Microstates and entropy
- Entropy of gases, liquids, solids
- Thermodynamic data tables
- Entropy and chemical reactions
- How to determine higher entropy state
- Mole of substance entropy analysis

Frequently Asked Questions

Which member in a pair of gases at the same temperature has higher entropy: a heavier gas molecule or a lighter one?

The gas with the higher molar mass (heavier molecule) generally has higher entropy because it has more available microstates due to its larger mass and increased degrees of freedom.

In a pair consisting of a crystalline solid and a gas at the same temperature, which has higher entropy?

The gas has higher entropy because gases have more disorder and a greater number of accessible microstates compared to solids.

Between two liquids at the same temperature, how do their entropies compare if one is more miscible or has a greater molecular complexity?

The more complex or more miscible liquid generally has higher entropy because it exhibits greater molecular disorder and more configurational

possibilities.

For two isotopes of the same element at the same temperature, which isotope has higher entropy?

The isotope with the greater mass (usually the heavier one) tends to have higher entropy due to increased vibrational and translational microstates.

When comparing the entropy of a pure substance in two different phases at the same temperature, which phase has higher entropy?

The phase with greater disorder, typically the gas phase, has higher entropy compared to solids and liquids.

Additional Resources

For One Mole Of Substance At A Given Temperature, Select The Member In Each Pair With The Higher Entropy

Understanding entropy and its implications in thermodynamics is crucial for chemists, physicists, and engineers alike. When considering for one mole of substance at a given temperature, select the member in each pair with the higher entropy, we delve into the core principles that govern the spontaneity of processes, the distribution of energy, and the nature of disorder within a system. This guide aims to clarify the concept, explain how to compare entropy between different states or configurations, and highlight its significance in real-world applications.

What Is Entropy and Why Is It Important?

Entropy (S) is a thermodynamic property that measures the degree of disorder or randomness within a system. It provides insight into the energy dispersal within the system and indicates the number of microscopic arrangements compatible with a macroscopic state.

- Key points about entropy:
- It tends to increase in spontaneous processes (Second Law of Thermodynamics).
- It is a state function, dependent only on the current state, not on the path taken.
- It helps determine the feasibility of reactions and phase changes.

In the context of one mole of substance at a given temperature, comparing the entropy of different possible states or configurations allows us to predict which states are more thermodynamically favored.

The Principle of Selecting the Member with Higher Entropy

When presented with pairs of states, configurations, or phase options for a given substance, selecting the member with the higher entropy aligns with the

natural tendency of systems to move toward greater disorder, provided the process is spontaneous and other conditions are favorable.

In practice:

- For equilibrium considerations, the state with higher entropy at constant temperature and pressure is more stable.
- When analyzing phase transitions or molecular arrangements, the configuration with higher entropy is more probable.

Thermodynamic Foundations: Linking Entropy to Spontaneity

The relationship between entropy and spontaneity is formalized in the Gibbs free energy (G):

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

Where:

- ΔG : Change in Gibbs free energy
- ΔH : Enthalpy change
- T: Temperature in Kelvin
- ΔS : Change in entropy

A process or transition is spontaneous if:

$$\Delta G < 0$$

Given a constant temperature and pressure, the process will tend toward the state with a larger ΔS (higher entropy), provided that the enthalpy change (ΔH) does not favor the opposite direction.

Comparing Entropy in Different States or Configurations

To select the member in each pair with the higher entropy, it's essential to understand how to evaluate or compare entropy values. Here are common scenarios:

1. Comparing Phases (Solid, Liquid, Gas)

- Generally, the phase with the higher entropy is the more disordered phase.

Phase	Relative Entropy	Explanation
Solid	Lowest	Particles are in fixed positions with minimal disorder.
Liquid	Intermediate	Particles are mobile but still relatively ordered.
Gas	Highest	Particles are widely separated and highly disordered.

Conclusion: When choosing between phases at the same temperature and pressure, select the phase with higher entropy – typically, the gas.

2. Comparing Molecular Configurations

- For molecules with different conformations or arrangements, the

configuration with more accessible microstates has higher entropy.

Example:

A flexible chain molecule can adopt many conformations, thus having higher entropy than a rigid structure.

3. Comparing States at Equal Energy

- When two states have the same energy, the state with more accessible microstates (higher degeneracy) has higher entropy.

Practical Examples

Let's explore some specific pairs or scenarios to illustrate how to determine which member has the higher entropy.

Example 1: Gas vs. Liquid at the Same Temperature

Question: Which has higher entropy, a mole of gas or a mole of liquid at 25°C?

Answer: The gas has higher entropy because its particles are more dispersed and have more accessible microstates.

Example 2: Two Different Phases of the Same Substance

Suppose you are comparing the entropy of ice (solid water) and water vapor at 0°C.

Answer: Water vapor (gas) has a significantly higher entropy due to its greater molecular disorder compared to ice.

Example 3: Isomers with Different Structures

Two isomers of the same molecular formula: one rigid and one flexible.

Question: Which has higher entropy?

Answer: The flexible isomer, because it can adopt more conformations, leading to higher microstate count and entropy.

Quantitative Approaches to Entropy Comparison

While qualitative judgments are often sufficient, sometimes quantitative data are necessary.

Standard molar entropy (S°) values are tabulated for many substances at standard conditions (usually 1 bar or 1 atm). Comparing these values provides a direct way to select the higher entropy member.

Example:

- $S^\circ(\text{O}_2, \text{ gas}) \approx 205 \text{ J}/(\text{mol}\cdot\text{K})$
- $S^\circ(\text{H}_2\text{O}, \text{ liquid}) \approx 70 \text{ J}/(\text{mol}\cdot\text{K})$

Since $205 > 70$, the gaseous oxygen has higher entropy.

Factors Affecting Entropy

Several factors influence the entropy of a state:

- Temperature: Increasing temperature generally increases entropy because particles move more vigorously.
- Mass and Molecular Complexity: More complex molecules with more atoms have higher entropy due to more possible arrangements.
- Phase and State: Gases > liquids > solids in entropy.
- Pressure: At constant temperature, decreasing pressure (expanding volume) increases entropy in gases.

Limitations and Considerations

While choosing the member with higher entropy is straightforward in many cases, consider the following:

- Enthalpy contributions: Sometimes, a state with higher entropy may have a higher enthalpy. The overall spontaneity depends on the combined effect in ΔG .
- Kinetic factors: Thermodynamic favorability (higher entropy) does not guarantee faster reaction rates.
- External constraints: Conditions like pressure, volume, and external work influence which state is more stable.

Significance in Real-World Applications

Understanding and applying the principle of selecting the member with higher entropy has numerous practical implications:

- Chemical reactions: Predicting which products or phases will form spontaneously.
- Material science: Designing materials that favor higher entropy configurations for stability.
- Thermodynamic cycles: Calculating efficiency in engines and refrigerators.
- Biological systems: Examining processes like protein folding and membrane formation, where entropy changes play a critical role.

Summary and Key Takeaways

- For one mole of substance at a given temperature, select the member in each pair with the higher entropy because systems tend to evolve toward greater disorder.
- Entropy comparisons depend on phase, molecular structure, microstates, and external conditions.
- The second law of thermodynamics favors states with higher entropy,

especially when coupled with favorable enthalpy changes.

- Quantitative data from standard molar entropy tables can guide accurate comparisons.
- Always consider the broader thermodynamic context, including enthalpy and external conditions, to determine spontaneity.

By mastering the principles outlined in this guide, you can confidently analyze thermodynamic systems, predict the most probable states, and understand the fundamental role of entropy in governing the natural behavior of substances at the molecular and macroscopic levels.

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