For Which Reaction Is G Expected To Be Closest To H?CO2(g) CO2(s)2NO(g) N2(g) + O2(g)H2O() H2O(s)NaCl(s)

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Understanding thermodynamic properties such as Gibbs free energy (G) and enthalpy (H) is fundamental in predicting the spontaneity and equilibrium of chemical reactions. When comparing G and H across different reactions, it's important to recognize the conditions under which these thermodynamic quantities are similar or differ significantly. This article explores the conditions and reactions where the Gibbs free energy (G) is expected to be closest to the enthalpy (H), providing insights into their thermodynamic relationships.

Introduction to Thermodynamic Quantities: G and H

What Is Gibbs Free Energy (G)?

Gibbs free energy, denoted as G, is a thermodynamic potential that measures the maximum reversible work obtainable from a system at constant temperature and pressure. It combines enthalpy and entropy (S), expressed as:

$$ G = H - TS $$

where:

- H is the enthalpy,
- T is the absolute temperature,
- S is the entropy.

A negative change in G (ΔG) indicates a spontaneous process under constant temperature and pressure.

What Is Enthalpy (H)?

Enthalpy (H) reflects the total heat content of a system at constant pressure. It accounts for the internal energy plus the work done by the system due to expansion or compression:

$$ H = U + PV $$

where:

- U is the internal energy,
- P is pressure,
- V is volume.

The change in enthalpy (ΔH) during a reaction signifies heat absorbed or released at constant pressure.

Relationship Between G and H

The key relationship:

$$ G = H - TS $$

indicates that Gibbs free energy differs from enthalpy by the entropy term multiplied by temperature. When the entropy change (ΔS) is small or zero, G and H tend to be closer in value. Conversely, significant entropy changes can cause G to deviate notably from H.

Analyzing the Given Reactions

The reactions provided are:

1. $CO_2(g) \rightarrow CO_2(s)$
2. $2NO(g) \rightarrow N_2(g) + O_2(g)$
3. $H_2O(l) \rightarrow H_2O(s)$
4. NaCl(s) (possibly dissolution or other processes)

The question focuses on identifying under which conditions G is expected to be closest to H among these reactions.

Reaction 1: $CO_2(g) \rightarrow CO_2(s)$

This process is the deposition of carbon dioxide, a phase change from gas to solid (dry ice).
- Thermodynamic considerations:
- Enthalpy change (ΔH) is negative; energy is released during freezing.
- Entropy change (ΔS) is negative since gas to solid reduces disorder.
- Expected G vs H relationship:
- Since both ΔH and ΔS are significant and negative, the term TS can be substantial at higher temperatures.
- At temperatures near the sublimation point, the difference between G and H becomes pronounced because TS influences G notably.

Reaction 2: $2NO(g) \rightarrow N_2(g) + O_2(g)$

This is a decomposition reaction involving nitrogen monoxide.
- Thermodynamic considerations:
- Typically, the reaction involves breaking bonds, requiring energy input, so ΔH may be positive or negative depending on conditions.
- Entropy change (ΔS) is positive because one molecule produces two gases, increasing disorder.
- Expected G vs H relationship:
- Since ΔS is positive, the TS term increases G, making G less negative or more positive relative to

□H, especially at higher temperatures.

- Therefore, G tends to deviate from H as temperature rises.

Reaction 3: H□O(l) □ H□O(s)

This is the freezing of water.

- Thermodynamic considerations:

- □H is negative; heat is released during freezing.

- □S is negative due to decreased disorder when liquid becomes solid.

- Expected G vs H relationship:

- Near the freezing point (0°C), entropy change is small, and the TS term is minimal.

- Consequently, G and H are very close in value at the melting/freezing point because the entropy term is negligible.

Reaction 4: NaCl(s) (dissolution or other process)

Depending on the process (dissolution, melting, etc.), thermodynamic properties vary.

- If NaCl dissolves:

- □H can be positive or negative depending on the process.

- □S generally increases because the salt disperses into solution, increasing disorder.

- Expected G vs H relationship:

- At conditions where entropy change is significant, G may differ notably from H.

Conditions Where G Is Closest To H

From the above analyses, the closeness of G to H depends on the magnitude of the TS term relative to □H and □S. Specifically:

- When ΔS is near zero or very small, the TS term is negligible, making G approximately equal to H.
- At or near the phase transition temperature where entropy change is minimal, G closely approximates H.

Ideal Reaction Conditions for G ≈ H

- At the phase transition temperature:
- For water freezing or melting (Reaction 3), at 0°C (273.15 K), ΔS is minimal, and G is close to H.
- Low-temperature conditions:
- For reactions involving gases condensing into solids (Reaction 1), at temperatures just below sublimation point, entropy change is small, and G approaches H.

Summary of Reactions and Their G and H Relationships

Reaction	Key Points	When G ≈ H?
$CO_2(g) \rightleftharpoons CO_2(s)$	Phase change with negative ΔH and ΔS	Near sublimation temperature, minimal entropy change
$2NO(g) \rightarrow N_2(g) + O_2(g)$	Entropy increases; ΔS positive	At low temperatures, entropy effect minimized
$H_2O(l) \rightarrow H_2O(s)$	Solidification; ΔH negative, ΔS negative	At freezing point, ΔS minimal
NaCl(s) (dissolution)	Depends on process; entropy often increases	Near saturation, where entropy change is small

Conclusion: The Reaction Where G Is Closest To H

Based on the thermodynamic principles and the conditions analyzed, the reaction where Gibbs free energy (G) is expected to be closest to enthalpy (H) is the freezing of water ($H_2O(l) \rightleftharpoons H_2O(s)$), especially at the freezing point (0°C or 273.15 K). This is because, at this temperature, the entropy change (ΔS) is near zero, minimizing the TS term and making G approximately equal to H.

In contrast, phase changes involving gases or reactions with significant entropy changes—such as the deposition of CO_2 or the decomposition of NO—exhibit larger differences between G and H due to the entropy term's influence.

Summary:

- The phase transition of water at 0°C is the reaction where G is closest to H.
- Reactions with minimal entropy change at their phase transition temperatures tend to have $G \approx H$.
- Understanding these relationships aids in predicting reaction spontaneity and designing processes in chemical engineering, environmental science, and material science.

Final Note:
While this analysis highlights the typical conditions under which G approximates H, actual thermodynamic behavior can vary with temperature, pressure, and specific reaction conditions. Accurate calculations require detailed thermodynamic data, but the principles outlined here serve as a strong foundation for understanding the relationship between G and H in various reactions.

Frequently Asked Questions

In which reaction is the change in Gibbs free energy (G) closest to the

change in enthalpy (H)?

The reaction where G is closest to H typically occurs when the entropy change (□S) is minimal or zero, such as the phase change from gas to solid, like CO2(g) to CO2(s).

Why is the reaction CO2(g) to CO2(s) likely to have G close to H?

Because this phase transition involves minimal entropy change at certain conditions, making G and H values nearly equal.

Among the listed reactions, which involves a phase change that makes G approximately equal to H?

The conversion of water vapor to ice (H2O(g) to H2O(s)) is a phase change where G closely approximates H under specific conditions.

Does the reaction NaCl(s) to NaCl(s) involve any change in G or H?

Since it's the same phase and substance, both G and H are essentially zero, so G is closest to H.

Which reaction among the options is most likely to have G □ H due to minimal entropy change?

The transition from N2(g) + O2(g) to their combined state has minimal entropy change, but since they remain separate gases, the phase change reactions like CO2(s) to CO2(g) are more relevant.

How does the phase change influence the relationship between G and H?

During phase changes like sublimation or condensation, the entropy change is small or zero at certain conditions, making G close to H.

Is the reaction 2NO(g) to N2(g) + O2(g) likely to have G close to H?

No, because it involves chemical transformation and entropy changes, so G and H are less likely to be close compared to phase changes.

What general principle explains when G is close to H in a reaction?

G is close to H when the temperature is near the phase transition point and the entropy change is negligible, such as in phase changes like sublimation or melting.

Additional Resources

For Which Reaction Is G Expected To Be Closest To H?

Understanding the relationship between Gibbs free energy (G) and enthalpy (H) is fundamental in thermodynamics, especially when predicting the spontaneity and equilibrium of chemical reactions. When analyzing various reactions, scientists often seek to determine under what conditions G closely approximates H, as this can simplify calculations and provide insights into the thermodynamic nature of the processes involved. In this context, a particular set of reactions involving carbon dioxide, nitrogen oxides, water, and sodium chloride presents an intriguing case for exploration. The question arises: for which of these reactions is G expected to be closest to H?

This article delves into the thermodynamic principles governing the relationship between G and H, examines the specific reactions in question, and elucidates the factors influencing their thermodynamic behaviors. Through this comprehensive analysis, readers will gain a deeper understanding of how and when G approximates H, grounded in the fundamental concepts of chemical thermodynamics.

Understanding the Thermodynamic Quantities: G, H, and S

Before analyzing the specific reactions, it’s crucial to establish a clear understanding of the thermodynamic quantities involved:

- Gibbs Free Energy (G):
Represents the maximum reversible work obtainable from a thermodynamic system at constant temperature and pressure. It predicts whether a reaction will proceed spontaneously ($\Delta G < 0$) or not ($\Delta G > 0$).

- Enthalpy (H):
Reflects the total heat content or energy stored within a system, primarily associated with bond energies.

- Entropy (S):
Measures the degree of disorder or randomness in a system.

The fundamental thermodynamic relationship linking these quantities is:

$$ G = H - TS $$

where T is the absolute temperature in Kelvin. This equation indicates that G differs from H by the TS term, which accounts for the entropy contribution scaled by temperature.

When Is G Closest To H? The Underlying Principles

Given the thermodynamic relation $G = H - TS$, the proximity of G to H depends on the magnitude of the TS term:

- At low temperatures:
The TS component becomes small, making G approach H.

- When the entropy change (ΔS) is negligible:

The TS term is minimal, and G closely mirrors H.

- For reactions with minimal entropy change:

G and H tend to be similar across a range of temperatures, especially at lower T.

In essence, G is expected to be closest to H when:

1. The reaction involves minimal changes in entropy ($\Delta S \approx 0$).
2. The temperature is relatively low, reducing the impact of the TS term.
3. The reaction occurs under conditions where the entropy change is thermodynamically insignificant.

The Reactions Under Consideration

The set of reactions under scrutiny includes:

1. $CO_2(g) \rightarrow CO_2(s)$
2. $2NO(g) \rightarrow N_2(g) + O_2(g)$
3. $H_2O() \rightarrow H_2O(s)$
4. NaCl(s) (lattice formation or dissolution processes are implied, but not specified as a reaction here)

Each of these reactions has unique thermodynamic characteristics, influenced by their physical states, bond energies, and entropy changes.

Analyzing Each Reaction

1. Carbon Dioxide: Gas to Solid ($CO_2(g) \rightarrow CO_2(s)$)

Thermodynamics:

- This reaction is essentially deposition (gas to solid), similar to dry ice sublimation or deposition.
- At low temperatures, CO_2 tends to exist as a solid; at higher temperatures, it sublimates into gas.
- Entropy change (ΔS):
Since gas has higher entropy than solid, the reaction involves a significant negative ΔS when going from gas to solid.

Implication:

- Because the entropy change is large and negative, TS becomes significant at higher temperatures, making G deviate notably from H.
- At low temperatures, the TS term diminishes, and G approaches H.

Conclusion:

- The reaction $CO_2(g) \rightarrow CO_2(s)$ is expected to have G closest to H at low temperatures where entropy effects are minimal.

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2. Nitrogen Oxides: $2NO(g) \rightarrow N_2(g) + O_2(g)$

Thermodynamics:

- This reaction involves converting two moles of NO gas into diatomic nitrogen and oxygen gases.
- The entropy change (ΔS):
Since the total number of gas moles remains the same (2 moles of NO produce 2 moles of N_2 and O_2), the entropy change is relatively small.

- Bond energies:

The reaction involves breaking and forming bonds, but overall, the number of particles remains consistent, implying a minimal change in entropy.

Implication:

- The small □S suggests that TS is less significant, and G will stay close to H over a broader temperature range.

Conclusion:

- The reaction 2NO(g) □ N□(g) + O□(g) is a strong candidate for G being close to H across various temperatures.

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3. Water: Liquid to Solid (H□O() □ H□O(s))

Thermodynamics:

- The phase change from liquid water to ice involves a significant decrease in entropy due to the increased order of the solid state.
- Entropy change (□S):
Large and negative, as the molecules become more organized.

- Enthalpy change (□H):
Includes the heat of fusion (~6 kJ/mol at 0°C).

Implication:

- At temperatures well below 0°C, the TS term is small, and G approximates H.
- Near the melting point, the entropy term becomes more significant, causing G to diverge from H.

Conclusion:

- H□O(s) □ H□O() is closest in G and H at low temperatures, far below the melting point.

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4. Sodium Chloride: NaCl(s)

Thermodynamics:

- NaCl solid is characterized by a lattice of ions; the process of dissolution involves breaking the lattice and forming aqueous ions.
- The formation of NaCl(s) from its constituent ions is typically highly exothermic, with minimal entropy change during formation.

Implication:

- Since the formation involves lattice energy with relatively small entropy change, G is close to H during formation or in stable solid form, especially at standard conditions.

Conclusion:

- For solid NaCl, G and H are expected to be close under standard conditions where entropy effects are minimal.

Comparative Summary: Which Reaction Has G Closest to H?

Based on the above analyses:

- $CO_2(g) \rightarrow CO_2(s)$: Close to H at low temperatures due to minimal entropy effects.
- $2NO(g) \rightarrow N_2(g) + O_2(g)$: Likely to have G close to H over a wide temperature range because of small ΔS.
- $H_2O() \rightarrow H_2O(s)$: Close at low temperatures, far from melting point.
- NaCl(s): G closely approximates H under standard conditions due to small entropy change.

Overall, the reaction $2NO(g) \rightarrow N_2(g) + O_2(g)$ is expected to have G closest to H across a broader range of conditions because of its minimal entropy change, making the TS term less influential.

Practical Significance and Applications

Understanding when G approximates H is not just an academic exercise; it has real-world implications:

- Predicting reaction spontaneity:
When $G \approx H$, calculations simplify, aiding in process design.

- Industrial processes:
For example, controlling temperature to ensure minimal entropy effects can optimize reactions like phase changes or gas conversions.

- Environmental chemistry:
Knowing thermodynamic tendencies of nitrogen oxides informs pollution control strategies.

Final Thoughts

The relationship between Gibbs free energy and enthalpy provides deep insights into the thermodynamic nature of chemical reactions. The degree to which G approximates H hinges primarily

on the entropy change and temperature. Among the reactions considered—CO_2 phase transition, nitrogen oxide conversion, water phase change, and sodium chloride formation—the reaction involving nitrogen oxides ($2NO(g) \rightarrow N_2(g) + O_2(g)$) stands out as the one most likely to have G closest to H over a wide range of conditions. Its minimal entropy change makes it thermodynamically predictable and manageable, illustrating the elegance and utility of fundamental thermodynamic principles.

In essence, recognizing the conditions under which G approximates H enables chemists and engineers to better predict reaction behavior, design efficient processes, and understand the energetic landscapes of chemical transformations.

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