Write A Balanced Chemical Equation For The Reaction Between Ferricyanide And Thiosulfate. Note That Only

Write A Balanced Chemical Equation For The Reaction Between Ferricyanide And Thiosulfate. Note That Only is a fundamental query in inorganic chemistry that involves understanding redox reactions, electron transfer processes, and the behavior of complex ions. This reaction is often studied in analytical chemistry, electrochemistry, and industrial processes where redox titrations are performed or where these compounds are involved in chemical syntheses. To develop a clear and accurate balanced chemical equation for this reaction, it is essential to understand the chemical nature of the reactants involved and their respective roles in the redox process.

Understanding the Reactants: Ferricyanide and Thiosulfate

Ferricyanide ($Fe(CN)_6^{3-}$)

Ferricyanide is a coordination complex consisting of an iron(III) center surrounded by six cyanide ligands. Its chemical formula is $Fe(CN)_6^{3-}$, and it is known for its stability and distinctive deep blue color. Ferricyanide acts primarily as an oxidizing agent because the iron(III) ion can be reduced to iron(II) (Fe^{2+}), which often results in a color change and is useful in various redox reactions.

Key properties:
- Oxidizing agent
- Stable in aqueous solutions
- Used in redox titrations

Thiosulfate ($S_2O_3^{2-}$)

Thiosulfate is a sulfur-containing oxyanion that acts predominantly as a reducing agent. It is often used in photographic fixing agents and in chemical analysis due to its ability to reduce various oxidants. Thiosulfate can undergo oxidation to tetrathionate or sulfate, depending on the reaction conditions, and it readily donates electrons in redox reactions.

Key properties:
- Reducing agent
- Used in titrations with iodine
- Can form various sulfur oxyanion species

General Redox Behavior of the Reactants

In the reaction between ferricyanide and thiosulfate, the primary process involves the reduction of ferricyanide to ferrocyanide and the oxidation of thiosulfate to tetrathionate or sulfate. The exact products depend on the reaction conditions such as pH, temperature, and the presence of catalysts or other ions.

Redox roles:
- Ferricyanide ($Fe(CN)_6^{3-}$): Oxidant (accepts electrons)
- Thiosulfate ($S_2O_3^{2-}$): Reductant (donates electrons)

This electron transfer results in the conversion of Fe(III) to Fe(II) and $S_2O_3^{2-}$ to higher oxidation state sulfur species.

Deriving the Balanced Chemical Equation

Step 1: Write the Unbalanced Skeleton Equation

The core reaction involves ferricyanide being reduced to ferrocyanide and thiosulfate being oxidized:
$Fe(CN)_6^{3-} + S_2O_3^{2-} \rightarrow Fe(CN)_6^{4-} + S_4O_6^{2-}$

However, this is a simplified view. In practice, thiosulfate is often oxidized to tetrathionate ($S_4O_6^{2-}$), and the specific products depend on conditions.

Step 2: Determine Oxidation States

- Iron in ferricyanide: +3
- Iron in ferrocyanide: +2
- Sulfur in thiosulfate: +2.5 (average oxidation state)
- Sulfur in tetrathionate: +2.5 (average)
- Sulfur in sulfate: +6 (oxidized form)

Step 3: Write Half-Reactions

Oxidation half-reaction (thiosulfate):
$$ \text{S}_2\text{O}_3^{2-} \rightarrow \text{S}_4\text{O}_6^{2-} + 2e^- $$
or
$$ 2\, \text{S}_2\text{O}_3^{2-} \rightarrow \text{S}_4\text{O}_6^{2-} + 2e^- $$

Reduction half-reaction (ferricyanide):

$$ \text{Fe(CN)}_6^{3-} + e^- \rightarrow \text{Fe(CN)}_6^{4-} $$

Note: The number of electrons transferred must be balanced across the two half-reactions.

Step 4: Balance Electrons and Combine

- Multiply the reduction half-reaction by 2 to match electrons:
$$ 2\, \text{Fe(CN)}_6^{3-} + 2e^- \rightarrow 2\, \text{Fe(CN)}_6^{4-} $$

- Combine with oxidation:
$$ 2\, \text{S}_2\text{O}_3^{2-} \rightarrow \text{S}_4\text{O}_6^{2-} + 2e^- $$

- Thus, the overall balanced reaction is:
$$ 2\, \text{Fe(CN)}_6^{3-} + 2\, \text{S}_2\text{O}_3^{2-} \rightarrow 2\, \text{Fe(CN)}_6^{4-} + \text{S}_4\text{O}_6^{2-} $$

Final Balanced Chemical Equation

The complete, balanced chemical equation for the redox reaction between ferricyanide and thiosulfate is:

$$ 2\, \text{Fe(CN)}_6^{3-} + 2\, \text{S}_2\text{O}_3^{2-} \rightarrow 2\, \text{Fe(CN)}_6^{4-} + \text{S}_4\text{O}_6^{2-} $$

Additional Considerations:
- The reaction typically occurs in aqueous solution, often under neutral or slightly alkaline conditions.
- pH can influence the exact oxidation products; in acid, sulfate formation is favored, whereas in neutral solutions, tetrathionate is common.
- The reaction is useful in analytical chemistry, especially titrations involving these ions.

Applications and Significance of the Reaction

This redox reaction has several practical applications:

- **Analytical Chemistry:** Used in titrations to quantify ferricyanide or thiosulfate concentrations.
- **Industrial Processes:** In processes where sulfur oxyanions are involved, such as in the purification of sulfur compounds.
- **Electrochemistry Studies:** Helps understand electron transfer and complex

ion behavior.

Moreover, understanding this reaction aids in designing sensors, developing redox flow batteries, and studying biological systems involving sulfur compounds.

Conclusion

Writing a balanced chemical equation for the reaction between ferricyanide and thiosulfate involves understanding their roles as oxidant and reductant, respectively, and balancing the electron transfer processes. The reaction exemplifies fundamental principles of redox chemistry, showcasing how complex ions and sulfur oxyanions interact under various conditions. The balanced reaction:

$$ 2\, \text{Fe(CN)}_6^{3-} + 2\, \text{S}_2\text{O}_3^{2-} \rightarrow 2\, \text{Fe(CN)}_6^{4-} + \text{S}_4\text{O}_6^{2-} $$

serves as an essential foundation for understanding related chemical processes and their applications across multiple scientific disciplines.

Frequently Asked Questions

What is the balanced chemical equation for the reaction between ferricyanide and thiosulfate?

The balanced chemical equation is: 2 [Fe(CN)6]^{3-} + 3 S2O3^{2-} → 2 [Fe(CN)6]^{4-} + 3 S4O6^{2-}.

Which oxidation states are involved in the reaction between ferricyanide and thiosulfate?

Ferricyanide contains Fe in a +3 oxidation state, which is reduced to Fe(II), while thiosulfate (S2O3^{2-}) is oxidized to tetrathionate (S4O6^{2-}).

What role does thiosulfate play in the redox reaction with ferricyanide?

Thiosulfate acts as a reducing agent, donating electrons to reduce ferricyanide (Fe^{3+}) to ferrocyanide (Fe^{2+}).

Are there any specific conditions required for the reaction between ferricyanide and thiosulfate?

The reaction typically occurs under aqueous, neutral or slightly alkaline conditions, without the need for catalysts, but pH can influence the rate and completeness.

How can the reaction between ferricyanide and thiosulfate be used analytically?

This redox reaction is used in titrations to determine concentrations of ferricyanide or thiosulfate in a solution.

What are the products formed when ferricyanide reacts with thiosulfate?

The primary products are ferrocyanide ([Fe(CN)6]^{4-}) and tetrathionate (S4O6^{2-}).

Why is balancing the chemical equation important in describing the reaction between ferricyanide and thiosulfate?

Balancing ensures the conservation of mass and charge, accurately representing the stoichiometry of reactants and products involved.

Can the reaction between ferricyanide and thiosulfate be used in photographic processing?

While similar redox reactions are used in photographic fixing, the specific reaction between ferricyanide and thiosulfate is mainly relevant in analytical chemistry, not standard photographic processes.

What is the significance of only considering certain ions in the reaction, as indicated by 'Note That Only'?

It emphasizes focusing on the primary reacting species (ferricyanide and thiosulfate), simplifying the reaction to those ions involved directly in the redox process.

How do you determine the coefficients when writing the balanced chemical equation for this reaction?

By balancing atoms for each element on both sides and ensuring charge

balance, typically through trial and adjustment of coefficients based on oxidation states and conservation principles.

Additional Resources

Write A Balanced Chemical Equation For The Reaction Between Ferricyanide And Thiosulfate. Note That Only is a fundamental task in inorganic chemistry, often encountered in analytical chemistry, redox titrations, and studies involving complex ions. Understanding how to accurately balance chemical equations not only clarifies the stoichiometry of the reaction but also provides insight into the underlying redox processes. This article offers a detailed, step-by-step guide to writing a balanced chemical equation for the reaction between ferricyanide and thiosulfate, emphasizing the importance of oxidation states, electron transfer, and proper balancing techniques.

Introduction to the Reactants

What is Ferricyanide?

Ferricyanide, with the chemical formula $[Fe(CN)_6]^{3-}$, is a coordination complex where iron is in the +3 oxidation state. It is a well-known oxidizing agent due to its ability to accept electrons readily. Its deep violet color makes it useful in various analytical applications, including redox titrations and spectrophotometry.

What is Thiosulfate?

Thiosulfate ($S_2O_3^{2-}$) is a sulfur-containing oxyanion that acts as a reducing agent. It is commonly used in photographic fixing, water treatment, and analytical chemistry for its ability to reduce certain species, including ferricyanide.

Understanding the Redox Nature of the Reaction

The reaction between ferricyanide and thiosulfate is a classic redox process involving electron transfer:

- Ferricyanide (Fe^{3+} in the complex) is reduced to ferrocyanide ($[Fe(CN)_6]^{4-}$).
- Thiosulfate ($S_2O_3^{2-}$) is oxidized, typically to tetrathionate ($S_4O_6^{2-}$) or sulfate (SO_4^{2-}), depending on the specific conditions.

The overall process involves the transfer of electrons from thiosulfate to ferricyanide.

Step-by-Step Guide to Writing the Balanced Equation

Step 1: Identify Oxidation States

- Ferricyanide: Iron in $[Fe(CN)_6]^{3-}$ has an oxidation state of +3.
- Ferrocyanide: Iron in $[Fe(CN)_6]^{4-}$ has an oxidation state of +2.
- Thiosulfate: $S_2O_3^{2-}$ contains sulfur in an oxidation state of +2 (average).
- Tetrathionate: $S_4O_6^{2-}$ has sulfur in an average oxidation state of +2.25, indicating oxidation.

Step 2: Write the Unbalanced Oxidation and Reduction Half-Reactions

Reduction of ferricyanide:

$$ \mathrm{Fe(CN)_6^{3-} + e^- \rightarrow Fe(CN)_6^{4-}} $$

Oxidation of thiosulfate:

$$ \mathrm{S_2O_3^{2-} \rightarrow S_4O_6^{2-} + e^-} $$

(Note: Thiosulfate oxidation to tetrathionate involves combining two $S_2O_3^{2-}$ ions.)

Step 3: Balance Each Half-Reaction

Reduction Half-Reaction:

$$
\mathrm{Fe(CN)_6^{3-} + e^- \rightarrow Fe(CN)_6^{4-}}
$$

Already balanced for atoms and charge.

Oxidation Half-Reaction:

Two thiosulfate ions combine to form one tetrathionate ion:

$$
2\, \mathrm{S_2O_3^{2-}} \rightarrow \mathrm{S_4O_6^{2-}} + 2\, e^-
$$

This accounts for the transfer of two electrons per pair of thiosulfate ions.

Step 4: Equalize Electron Transfer

The reduction consumes 1 electron per ferricyanide, while oxidation produces 2 electrons per pair of thiosulfate ions. To balance electrons:

- Multiply the reduction half-reaction by 2:

$$
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$$
2\, \mathrm{Fe(CN)_6^{3-} + 2\, e^- \rightarrow 2\, \mathrm{Fe(CN)_6^{4-}}}
$$

- Oxidation remains as:

$$
2\, \mathrm{S_2O_3^{2-}} \rightarrow \mathrm{S_4O_6^{2-}} + 2\, e^-
$$

Now, electrons are balanced (both sides involve 2 electrons).

Step 5: Combine the Half-Reactions

Adding the reduced and oxidized forms:

$$
2\, \mathrm{Fe(CN)_6^{3-}} + 2\, \mathrm{S_2O_3^{2-}} \rightarrow 2\, \mathrm{Fe(CN)_6^{4-}} + \mathrm{S_4O_6^{2-}}
$$

This is the preliminary, unbalanced overall reaction.

Step 6: Confirm Atom and Charge Balance

- Atoms:

- Fe: 2 on both sides.
- C: 12 on both sides (6 C per complex ion, 2 complexes).
- N: 12 on both sides.
- S: 4 on both sides.
- O: 6 from 2 thiosulfate (each $S_2O_3^{2-}$ has 3 O), totaling 6 O on the left; 6 O in $S_4O_6^{2-}$ on the right.

- Charge:

- Left: 2× $[Fe(CN)_6]^{3-}$ = 2×(-3) = -6; 2× $S_2O_3^{2-}$ = 2×(-2) = -4; total = -10.
- Right: 2× $[Fe(CN)_6]^{4-}$ = 2×(-4) = -8; $S_4O_6^{2-}$ = -2; total = -10.

Charges are balanced.

Final Balanced Chemical Equation

Write the complete balanced equation:

$2\ [Fe(CN)_6]^{3-} + 2\ S_2O_3^{2-} \rightarrow 2\ [Fe(CN)_6]^{4-} + S_4O_6^{2-}$

This equation accurately represents the redox process where ferricyanide is reduced to ferrocyanide, and thiosulfate is oxidized to tetrathionate.

Additional Considerations

Reaction Conditions

- The reaction typically occurs in aqueous solution at neutral or slightly alkaline pH.
- It’s essential to maintain appropriate conditions to prevent side reactions, such as sulfate formation or complex decomposition.

Applications of the Reaction

- Analytical Chemistry: Used in titrations to determine concentrations of ferricyanide or thiosulfate.
- Redox Chemistry Education: Demonstrates electron transfer and balancing techniques.
- Environmental Chemistry: Understanding sulfur oxidation processes.

Common Mistakes to Avoid

- Incorrect oxidation states: Always verify oxidation states before balancing.
- Miscounting electrons: Ensure electrons lost and gained match.
- Ignoring complex ion charges: Remember the charges on the coordination complexes.
- Overlooking reaction conditions: Some reactions may favor different oxidation products under varying pH or temperature.

Summary

Writing a balanced chemical equation for the reaction between ferricyanide and thiosulfate involves:

- Recognizing the redox nature of the process.
- Determining the oxidation states.
- Writing and balancing the half-reactions.
- Ensuring electrons are balanced.
- Combining the half-reactions to produce the overall balanced equation.

By following these steps, chemists can accurately model and utilize this reaction in laboratory and industrial contexts. Mastery of such balancing techniques enhances understanding of redox chemistry and supports the development of precise analytical methods.

Final Notes

Understanding the reaction between ferricyanide and thiosulfate not only fosters a solid grasp of redox principles but also illustrates the importance of careful stoichiometric analysis. Whether used in titrations, environmental monitoring, or educational demonstrations, this reaction exemplifies core concepts in inorganic chemistry.

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