Compound[Cr(NH3)(en)2Cl]Br2,thecoordination Number (C.N.) And Oxidation Number (O.N.) Of Themetalatom

Compound[Cr(NH3)(en)2Cl]Br2, the coordination number (C.N.) and oxidation number (O.N.) of the metal atom

Understanding the structure and properties of coordination compounds is fundamental in inorganic chemistry. Among these, complex compounds involving transition metals like chromium are particularly significant due to their diverse applications in catalysis, materials science, and biological systems. One such compound is [Cr(NH3)(en)2Cl]Br2, which exemplifies key concepts such as coordination number (C.N.) and oxidation number (O.N.) of the central metal atom. This article delves into the detailed analysis of this compound, elucidating its structure, calculating the coordination number, determining the oxidation state of chromium, and exploring the significance of these parameters in the context of inorganic chemistry.

Understanding the Compound [Cr(NH3)(en)2Cl]Br2

Structural Overview

The chemical formula [Cr(NH3)(en)2Cl]Br2 describes a coordination complex comprising a chromium metal center, ligands attached to it, and counterions balancing the charge. Let's break down each component:

- Central Metal Atom: Chromium (Cr)
- Ligands Attached to Cr:
- NH3 (Ammonia): A neutral monodentate ligand.
- en (Ethylenediamine): A bidentate ligand, coordinating through two nitrogen atoms.
- Cl (Chloride): A monodentate ligand, negatively charged.
- Counterions: Two bromide ions (Br−) outside the coordination sphere, balancing the overall charge.

This complex is a coordination entity where ligands are attached to the metal atom through coordinate covalent bonds, forming a stable structure.

Determining the Coordination Number (C.N.)

Definition of Coordination Number

The coordination number (C.N.) of a metal atom in a complex refers to the total number of ligand donor atoms directly bonded to the metal center. It provides insight into the geometry and stability of the complex.

Calculating the Coordination Number for $[Cr(NH_3)(en)_2Cl]Br_2$

To determine the coordination number:

1. Identify Ligands and Their Donor Atoms:

- NH_3: Donates one lone pair via its nitrogen atom.
- en (Ethylenediamine): Bidentate ligand donating two lone pairs through two nitrogen atoms.
- Cl: Monodentate ligand donating one lone pair via its chloride ion.

2. Count the Donor Atoms:

- NH_3: 1 donor atom (N)
- en: 2 donor atoms (both N)
- Cl: 1 donor atom (Cl)

3. Calculate Total Donor Atoms:

- 1 (from NH_3) + 2 (from en) + 1 (from Cl) = 4

Hence, the coordination number of chromium in $[Cr(NH_3)(en)_2Cl]Br_2$ is 4.

Determining the Oxidation Number (O.N.) of Chromium

Definition of Oxidation Number

The oxidation number (O.N.) of a metal in a complex indicates its oxidation state, reflecting the degree of oxidation or reduction relative to its elemental form. It is essential for understanding the electron distribution and reactivity.

Calculating the Oxidation Number of Cr in $[Cr(NH_3)(en)_2Cl]Br_2$

To find the oxidation number:

1. Identify the charges of ligands and counterions:

- NH_3: Neutral ligand, O.N. contribution = 0
- en (ethylenediamine): Neutral ligand, O.N. contribution = 0
- Cl (chloride): Ligand with a charge of −1 (monodentate)
- Br (bromide): Counterion with a charge of −1 per ion

2. Determine the overall charge of the complex cation:

The entire complex is neutral or charged?

Since the formula indicates $[Cr(NH_3)(en)_2Cl]Br_2$, the complex cation is associated with two Br^- ions, making the overall compound neutral.

3. Calculate the total charge of the complex cation:

- Total negative charge from the two bromide ions: $2 \times (-1) = -2$

- The complex cation must have a charge of +2 to balance the −2 from bromides (since overall neutral).

4. Set up the equation for the oxidation number of Cr:

Let O.N. of chromium = x

Sum of charges:

x (from Cr) + 0 (NH_3) + 0 (en) + (−1 for Cl) = +2 (overall charge of the complex cation)

Simplify:

$x - 1 = +2$

Therefore,

$x = +3$

Thus, the oxidation number of chromium in $[Cr(NH_3)(en)_2Cl]Br_2$ is +3.

Significance of Coordination Number and Oxidation Number

Coordination Number

The coordination number influences the geometry and reactivity of the complex:

- For C.N. = 4, common geometries include tetrahedral and square planar structures.
- The specific ligand types and their arrangements determine the precise geometry.

In this case, with a C.N. of 4, the complex likely adopts a tetrahedral or square planar configuration, with implications for its electronic properties.

Oxidation Number

Knowing the oxidation number helps:

- Understand electron distribution and bonding nature.
- Predict magnetic and spectral properties.
- Assess reactivity and stability.
- Facilitate synthesis of related compounds or catalysts.

Chromium in +3 oxidation state is common, often leading to colored complexes and significant biological activity.

Structural and Geometrical Aspects of $[Cr(NH_3)(en)_2Cl]Br_2$

Geometry and Shape

Given the coordination number of 4, the complex can adopt:

- **Tetrahedral geometry:** Generally favored when ligands are large or less electrostatically intense.
- **Square planar geometry:** Common in d8 metal complexes but less typical for Cr(III) which is d3 configuration.

Most likely, the complex adopts a tetrahedral geometry due to the nature of ligands and the metal oxidation state.

Bonding and Ligand Arrangement

- The bidentate en ligand occupies two positions, wrapping around the metal atom to form chelate rings, contributing to the stability of the complex.
- Monodentate ligands such as NH_3 and Cl occupy the remaining positions.

Applications and Importance of $[Cr(NH_3)(en)_2Cl]Br_2$

Understanding the coordination number and oxidation state of the metal atom in such complexes has practical implications:

- Catalysis: Cr(III) complexes are used as catalysts or catalyst precursors in organic synthesis.
- Biological Systems: Similar complexes mimic biological chromium compounds involved in glucose metabolism.
- Material Science: These complexes serve as components in dyes, pigments, and magnetic materials.

Summary

In summary, the complex [Cr(NH3)(en)2Cl]Br2 features a chromium ion with a coordination number of 4, primarily due to four ligand donor atoms (one from NH3, two from en, and one from Cl). The oxidation number of chromium in this compound is +3, as deduced from ligand charges and overall neutrality. These parameters are crucial in understanding the complex's structure, stability, and reactivity, and they highlight the importance of coordination chemistry in various scientific fields.

Final Notes

- The coordination number and oxidation number are fundamental concepts in inorganic chemistry, aiding in the classification and prediction of properties of metal complexes.
- Accurate determination requires careful analysis of ligand types, charges, and overall charge balance.
- Complexes like [Cr(NH3)(en)2Cl]Br2 serve as excellent models for studying metal-ligand interactions and their applications in industry and biology.

Keywords for SEO Optimization:
- Coordination number in complex compounds
- Oxidation number of chromium in coordination complexes
- [Cr(NH3)(en)2Cl]Br2 structure and properties
- Inorganic chemistry of transition metal complexes
- Ligand types and bonding in coordination chemistry
- Crystal field theory and geometries of coordination compounds

Frequently Asked Questions

What is the coordination number (C.N.) of the metal atom in the compound [Cr(NH3)(en)2Cl]Br2?

The coordination number is 6, as the metal atom is bonded to two en (ethylenediamine), one NH3, and one Cl ligand, totaling 4 ligands directly attached; however, considering the complex cation, the total ligands coordinated to Cr are 6, including the bridging Cl if present. In this specific case, the coordination number is 6.

How do you determine the oxidation number (O.N.) of chromium in [Cr(NH3)(en)2Cl]Br2?

The oxidation number of Cr is calculated by considering the charges of the ligands and counterions. NH3 and en are neutral, Cl is typically -1, and the entire complex is neutral. Given two Br^- ions outside the complex, the complex cation must have a total charge of +2 to balance the two Br^- ions. Therefore, the O.N. of Cr is +3.

What are the ligands present in the complex [Cr(NH3)(en)2Cl]Br2?

The ligands are one ammonia (NH3), two ethylenediamine (en) molecules, and one chloride (Cl). The two bromide ions are counterions outside the coordination sphere.

Is the oxidation state of chromium in [Cr(NH3)(en)2Cl]Br2 +3 or +2?

The oxidation state of chromium is +3, determined by considering the neutrality of the complex and the charges of the ligands and counterions.

How does the nature of ligands like en and NH3 influence the oxidation number of the metal in coordination complexes?

Ligands like en and NH3 are neutral, so they do not affect the oxidation number directly; the oxidation number is determined by the overall charge balance of the complex and counterions. Their presence helps stabilize specific oxidation states without altering the charge contributed by the metal.

Why is the coordination number in [Cr(NH3)(en)2Cl]Br2 considered 6?

Because the metal atom is bonded to six ligand donor atoms: four from the two bidentate en ligands (each en contributes two donor atoms) and one each from NH3 and Cl, making a total of six coordination sites occupied.

Can the oxidation number of chromium in this complex change if ligands are varied?

Yes, replacing neutral ligands like NH3 or en with negatively charged ligands can alter the oxidation number of chromium, depending on the charges of the new ligands and the overall charge balance of the complex.

Additional Resources

Compound $[Cr(NH_3)(en)_2Cl]Br_2$, the Coordination Number (C.N.) and Oxidation Number (O.N.) of the Metal Atom

In the fascinating field of coordination chemistry, understanding the intricacies of complex compounds provides vital insights into their structure, reactivity, and properties. Among these, the complex $[Cr(NH_3)(en)_2Cl]Br_2$ presents an intriguing case study, combining various ligands and a transition metal center. Analyzing its coordination number (C.N.) and oxidation number (O.N.) not only aids in deciphering its structural framework but also enhances our comprehension of transition metal chemistry. This article delves deeply into these concepts, unraveling the structure of this complex and highlighting the significance of these parameters in coordination compounds.

Understanding the Compound: An Overview

Before diving into the specifics of coordination and oxidation states, it is essential to grasp the fundamental makeup of the compound.

Chemical Formula: $[Cr(NH_3)(en)_2Cl]Br_2$

Key Components:
- Chromium (Cr): The central metal atom.
- Ligands:
- Ammonia (NH_3): A neutral monodentate ligand.
- Ethylenediamine (en): A bidentate ligand, coordinating via two nitrogen atoms.
- Chloride (Cl): A monodentate ligand, typically negatively charged.
- Counter Ions: Two bromide ions (Br^-) outside the coordination sphere.

This complex is an example of a coordination compound where diverse ligands coordinate to a transition metal, forming a stable, discrete entity.

The Coordination Number (C.N.): Definition and Determination

What is the Coordination Number?

The coordination number of a metal atom within a complex refers to the number of ligand donor atoms directly bonded to it. This number reflects the metal's immediate bonding environment and influences the geometry and stability of the complex.

How to Determine the Coordination Number in $[Cr(NH_3)(en)_2Cl]Br_2$

1. Identify the Ligands and Their Donor Atoms:
- NH_3 (Ammonia): Donates one lone pair via nitrogen, acting as a monodentate ligand.
- en (Ethylenediamine): A bidentate ligand donating two lone pairs, coordinating via two nitrogen atoms.
- Cl (Chloride): Donates one lone pair via chloride ion, acting as a monodentate ligand.

2. Count the Ligand Donor Atoms Bonded to the Metal:
- NH_3: 1 donor atom (N).
- en: 2 donor atoms (both N atoms).
- Cl: 1 donor atom (Cl).

3. Sum the Donor Atoms:

Total donor atoms = 1 (NH_3) + 2 (en) + 1 (Cl) = 4.

Result: The Coordination Number (C.N.) is 4.

Geometrical Implications of a C.N. of 4

The coordination number of 4 opens up several possible geometries, with the most common being:

- Tetrahedral: Characterized by bond angles of approximately 109.5°. Typically observed in complexes with less electronic repulsion and symmetric ligand distribution.
- Square Planar: Characterized by a flat, rectangular arrangement. Common in d^8 metal complexes (e.g., Ni(II), Pd(II)).

For Cr(III) complexes with C.N. = 4, the geometry is often octahedral or tetrahedral. However, the presence of bidentate and monodentate ligands influences the geometry.

In $[Cr(NH_3)(en)_2Cl]$, considering the ligand types and their bonding modes, the complex most likely adopts a tetrahedral or distorted tetrahedral geometry, although some literature suggests a square planar configuration for similar complexes under specific conditions.

The Oxidation Number (O.N.): Definition and Calculation

What is the Oxidation Number?

The oxidation number of a metal in a complex indicates the apparent charge it has, considering the ligands as if they were fully ionic. It reflects the degree of oxidation of the metal atom.

Steps to Calculate O.N. in $[Cr(NH_3)(en)_2Cl]Br_2$

1. Identify the Charges of Ligands:
- NH_3: Neutral (charge = 0).
- en (ethylenediamine): Neutral (charge = 0).
- Cl (chloride): Typically, chloride in complexes acts as Cl^- (charge = -1).
- Br (bromide): Outside the coordination sphere, the two Br^- ions are counter ions, each with a charge of -1.

2. Set Up the Charge Balance Equation:

Let x be the oxidation number of chromium (Cr).

The total charge contributed by ligands:
- NH_3: 0
- en: 0
- Cl: -1 (since it's a monodentate ligand bound to the metal)

The complex ion $[Cr(NH_3)(en)_2Cl]$ has an overall charge of $x + (0) + (0) + (-1) = x - 1$.

The entire compound is neutral, but the two bromide ions outside the complex contribute a total charge of -2, balancing the complex cation:

Charge balance:

$$
\text{Complex cation charge} + \text{Counter ions} = 0
$$

$$
(x - 1) + (-2) = 0
$$

$$
x - 1 - 2 = 0
$$

$$
x = +3
$$

Result: The Oxidation Number (O.N.) of Cr is +3.

Significance of Oxidation and Coordination Numbers

Understanding these parameters is crucial for deciphering the properties of the complex:

- Oxidation Number (+3):
- Corresponds to Cr(III), a common oxidation state for chromium.
- Indicates the complex's electron configuration, magnetic properties, and potential reactivity.
- Cr(III) often exhibits magnetic moments due to unpaired electrons and participates in various biological and industrial processes.

- Coordination Number (4):
- Influences the geometry, which in turn affects reactivity and physical properties.
- A C.N. of 4 can lead to tetrahedral or square planar geometries, each with distinct characteristics.
- The presence of bidentate ligands like en stabilizes specific geometries, often favoring tetrahedral arrangements.

Broader Context and Applications

The coordination chemistry of chromium complexes such as $[Cr(NH_3)(en)_2Cl]Br_2$ is more than academic curiosity. These compounds have practical implications:

- Catalysis: Many chromium complexes serve as catalysts in organic synthesis.
- Biological Role: Cr(III) is an essential trace element involved in glucose metabolism.
- Material Science: Such complexes are studied for their magnetic and optical properties.

Additionally, understanding ligand behavior, geometry, and oxidation states enables chemists to design complexes with tailored properties for specific applications.

Summary and Conclusion

The complex $[Cr(NH_3)(en)_2Cl]Br_2$ exemplifies the nuanced interplay of ligand types, geometries, and oxidation states in coordination chemistry. Its coordination number of 4 reflects a bonding environment where four donor atoms—one from ammonia, two from the bidentate ethylenediamine, and one from chloride—coordinate to the chromium center. The oxidation number of +3 indicates chromium is in its +3 oxidation state, a common and stable form for this metal.

Understanding these parameters not only provides insights into the structure and stability of the complex but also lays the foundation for exploring its reactivity, magnetic properties, and potential applications. As coordination chemistry continues to evolve, such detailed analyses remain vital for advancing both fundamental science and practical innovations.

In essence, $[Cr(NH_3)(en)_2Cl]Br_2$ showcases the elegant complexity of transition metal coordination compounds, where ligand types, geometries, and oxidation states coalesce to define a molecule's identity and function.

Compound Cr Nh3 En 2cl Br2 Thecoordination Number C N And Oxidation Number O N Of Themetalatom

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