

Synthesis and Antibacterial Studies of Some Bivalent Transition Metal Ions Zn (II), Cu (II) and Ni (II) Complexes of Schiff's Base Derived from Some Substituted Aromatic Aldehydes

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Abstract

In this study, Schiff bases were synthesised through the condensation of aromatic aldehydes with primary amines and subsequently complexed with Ni(II), Zn(II) and Cu(II) ions. The formation of the metal complexes was confirmed by FTIR spectroscopy, which identified the key functional groups involved in coordination. The biological activity of the prepared compounds were studied with the help of selected bacteria like E. coli, Pseudomonas and B. cereus. The results obtained shows that the Schiff bases coordinate with the Ni(II), Zn(II) and Cu(II) ions through nitrogen atom. The complexes of Ni(II), Zn(II) and Cu(II) with Schiff's base as a ligand had been identified with the help of elemental analysis, molecular weight determinations and by FTIR spectra. The interpretation IR spectra represents that the Schiff's bases ligand coordinated to Zn(II), Cu(II) and Ni(II) metal ions through the nitrogen atom

Keywords: Ni(II) complex, Cu(II) Schiff base complex, FTIR spectroscopy, antimicrobial activity

INTRODUCTION

The co-ordination chemistry of metal complexes of transition as well as inner transition metal ions with active Schiff's base ligands has versatile applications and properties in the various fields such as pharmacological, antibacterial [1], antifungal [2], antitumor [3] and antimalarial activities. The transition metal complexes of Schiff bases ligands and their respective biological, anti-malarial, anti-cancer activities have been reported and investigated in various research studies [4]. Most of the Schiff's base metal complexes derivatives shows versatile range of activities were studied and presented in various research studies [5-8]. Schiff bases derived formed by the condensation of R-NH₂ with R-CHO or -C=O, forming a characteristic azomethine (-C=N-) group [9-12]. Their ability to act as ligands and form stable complexes with transition metals has made them important in coordination chemistry. Among transition metals, Ni(II) and Cu(II) are of particular interest due to their favourable coordination behaviour and biological relevance. FTIR spectroscopy serves as a key technique in confirming the coordination of

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Received Date: May 31, 2025

Accepted Date: June 26, 2025

Published Date: August 25, 2025

Citation: Ashok N. Patange, Akansha Vemul, Aahana Alvares, Mamta Ram. Synthesis and antibacterial studies of some bivalent transition metal ions Zn (II), Cu (II) and Ni (II) complexes of Schiff's base derived from some substituted aromatic aldehydes. Journal of Modern Chemistry & Chemical Technology. 2025; 16(2): 96–104p.

metal ions by identifying changes in functional group vibrations, especially the azomethine bond. This study reports [13-15] the synthesis of Schiff bases from aromatic aldehydes and primary amines, their complexation with Ni (II) and Cu (II) ions, and the evaluation of their antimicrobial activity against selected microbial strains.

EXPERIMENTAL

All chemicals used were of A.R grade and purchased from S.D Fine company (Mumbai). This experimental part divided in to six parts,

Preparation Of Schiff's Base (L_1) From O-Nitro Benzaldehyde And α -Naphthylamine

Take 1.51 gm (0.01m) of o-nitro benzaldehyde and 1.43gm (0.01m) of α -naphthylamine., Dissolve both separately in minimum quantity of ethanol. Mix the solutions [16-18] Slowly add the α -naphthylamine solution into the o-nitro benzaldehyde solution while stirring continuously. Adding glacial acetic acid – To maintain the pH. Allow the reaction mixture to cool at room temperature, then place it in an ice bath to promote crystallization of the Schiff base. Filter the solid product using vacuum filtration. Wash the collected solid with cold ethanol and then with cold distilled water to remove unreacted starting materials. Dry the Schiff base product in an oven at around 50–60°C or at room temperature under vacuum.

Synthesis of Schiff Base (L_2) from p-anisaldehyde and α -Naphthylamine

Take 1.2ml of p-anisaldehyde and 1.32gm(0.01m) of α -naphthylamine[19-20], Dissolve both separately in minimum quantity of ethanol. Mix the solutions: Slowly add the α -naphthylamine solution into the p-anisaldehyde solution while stirring continuously. Adding glacial acetic acid – To maintain the PH. The reaction mixture is reflux for 2 hours, the crystals of the compound formed when cooled place it in an ice bath. The precipitate formed is filter through the suction and dried and purified

Synthesis of Schiff Base (L_3) from 4-bromobenzaldehyde and α -Naphthylamine

Take 1.887gm of 4-bromobenzaldehyde and 1.38gm(0.01m) of α -naphthylamine. Dissolve both separately in minimum quantity of ethanol. Mix the solutions: Slowly add the α -naphthylamine solution into the 4-bromobenzaldehyde solution while stirring continuously. The pH of reaction mixture maintained by adding glacial acetic acid The reaction mixture is reflux for 2 hours, the crystals of the compound formed when cooled place it in an ice bath. The precipitate formed is filter through the suction and dried and purified. Dry the Schiff base product in an oven at around 50–60°C or at room temperature under vacuum.

Preparation of $[Zn(L_1)_4]Cl_2$, $[Cu(L_1)_4]Cl_2$ and $[Ni(L_1)_2]Cl_2$ Complexes

Dissolve the Schiff base ligand(L_1) (2.37gm) in a minimum amount of warm ethanol [21] Dissolve Nickel (II) (4.74gm) in ethanol. Mix the solutions, Slowly add the Nickel(II) salt solution into the Schiff base solution while stirring continuously. Stir the reaction mixture at room temperature or slightly warm it (around 40–50°C, optional) for about 2–3 hours. Formation of complex: A coloured precipitate (often green, bluish-green, or dark colour) will form, indicating the formation of the Ni(II) complex. Cooling: If necessary, place the reaction mixture in an ice bath for about 30 minutes to maximize precipitation. Filtration: Filter the solid complex by vacuum filtration. Wash the solid with small amounts of cold ethanol and then cold distilled water to remove unreacted materials and salts. Drying: Dry the Nickel (II) complex at room temperature or in an oven at around 50°C. In the same way Zn (II) and Cu(II) complexes were prepared using the respective meatal salts.

Preparation of $[Zn(L_2)_4]Cl_2$, $[Cu(L_2)_4]Cl_2$ and $[Ni(L_2)_2]Cl_2$ Complexes

Dissolve the Schiff base ligand (L_2 , L_3) (0.800gm) in a minimum amount of warm ethanol., dissolve Copper (II) (0.410gm) in ethanol. Mix the solutions: Slowly add the Copper (II) salt solution into the Schiff base solution while stirring continuously. Stirring: Stir the reaction mixture at room temperature

or slightly warm it (around 40–50°C, optional) for about 2–3 hours. Formation of complex: A coloured precipitate (often green, bluish-green, or dark colour) will form, indicating the formation of the Cu(II) complex. Cooling: If necessary, place the reaction mixture in an ice bath for about 30 minutes to maximize precipitation. Filtration: Filter the solid complex by vacuum filtration. Wash the solid with small amounts of cold ethanol and then cold distilled water to remove unreacted materials and salts. Drying: Dry the Cu(II) complex at room temperature or in an oven at around 50°C. In the same way Zn (II) and Ni(II) complexes were prepared using the respective metal salts.

RESULT AND DISCUSSION

~1610 cm⁻¹ confirms (C=N) group.

~1570, 1517, 1440 cm⁻¹ (C=C) Stretch confirms Benzene and Naphthalene systems. Figure 1

~1340-1370 cm⁻¹ NO₂ group present.

~3500 - 3000 cm⁻¹ -OH or -NH might be from groups Schiff base.

~1600 cm⁻¹ (C=N) group present. (In free Schiff base this band typically appears at 1620 - 1650 cm⁻¹ but due to the presence of Ni(II) it shifts to the lower wave number [22].

~1000 - 4000 cm⁻¹ (Metal ligand vibrations). Sharp peak 500 cm⁻¹ Ni-N stretching vibration indicating coordination of the Nitrogen from the Schiff base to the Ni(II) ion. Figure 2

~3400 cm⁻¹ (Broad): O-H stretch (alcohols, phenols, carboxylic acids) — typically broad and strong. N-H stretch (amines or amides) — may be less broad, sometimes double peaks for primary amines. Figure 3

~3000–3100 cm⁻¹: C-H stretch for alkenes or aromatics (sp² hybridized). Peaks just below 3000 cm⁻¹: C-H stretch for alkanes (sp³ hybridized).

~2200–2300 cm⁻¹: C≡C or C≡N (alkyne or nitrile stretches) — usually sharp and weak to medium. ~1700 cm⁻¹ (Strong): C=O stretch — a strong indicator of carbonyl-containing compounds (ketones, aldehydes, esters, acids, amides).

~1600 cm⁻¹ and ~1500 cm⁻¹: C=C stretch (aromatic rings, alkenes). May show multiple medium-intensity peaks indicative of aromatic systems.

1300–1000 cm⁻¹: C-O stretches — typical for alcohols, esters, and carboxylic acids. Also fingerprint region — complex but useful for compound identification.

~3300–3500 cm⁻¹ Suggests O-H stretching (from alcohols, phenols, or carboxylic acids) Could also be N-H stretching if the sample contains amines or amides.

Sharp strong peak near ~1700 cm⁻¹ Indicative of C=O stretching, common in carbonyl compounds: ketones, aldehydes, esters, acids.

~1600 cm⁻¹ and ~1500 cm⁻¹ region Likely C=C stretching, possibly aromatic rings or alkenes.

~1000–1300 cm⁻¹ Typically associated with C-O stretching (alcohols, ethers, esters). No strong signals around ~2200 cm⁻¹ Likely absence of nitriles (C≡N) or alkynes (C≡C). Figure 4

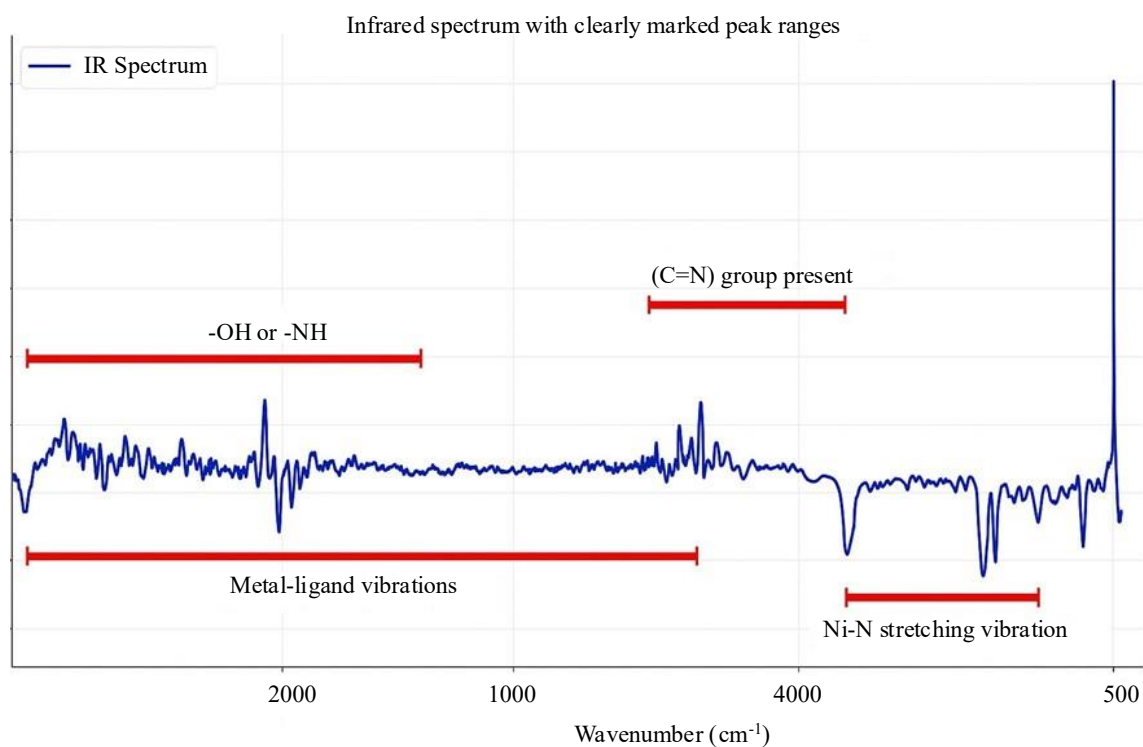


Figure 2. IR spectrum of Ni (II) metal complex (ML₁).

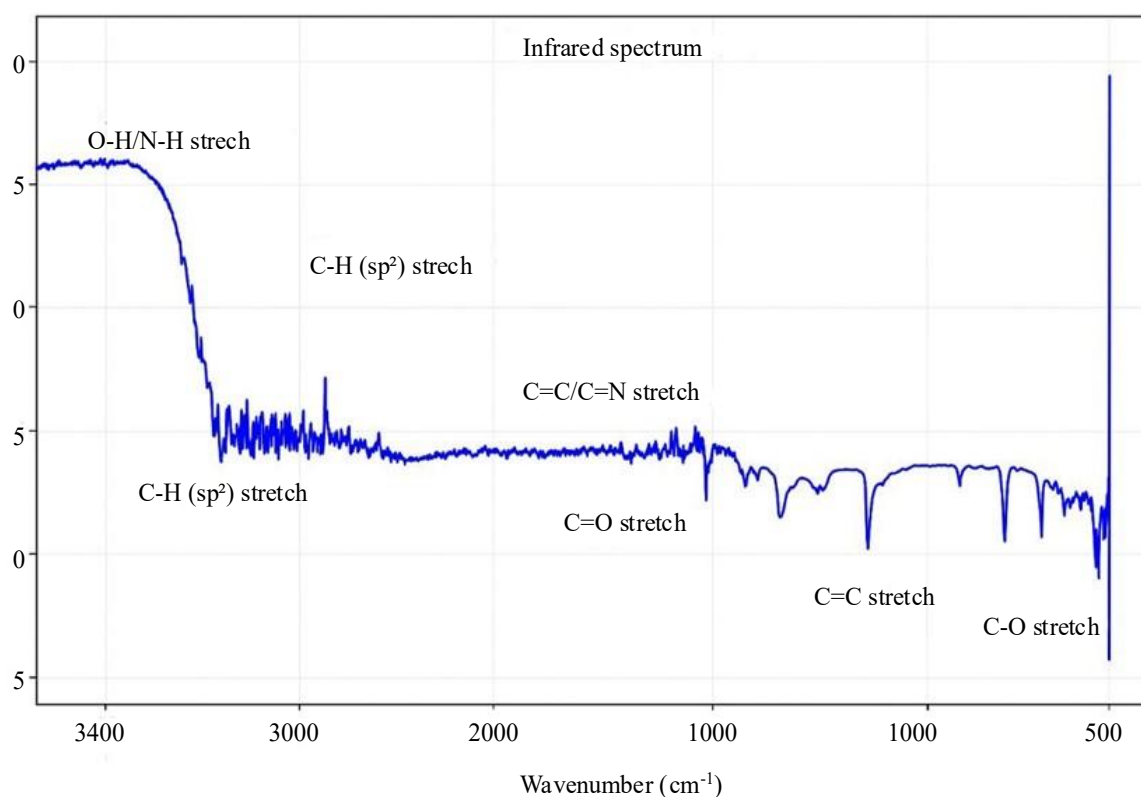


Figure 3. IR spectrum of schiff base Ligand (L₂) (α -naphthylamine and p-anisaldehyde).

Based on spectrum - Around (1000-500cm⁻¹) suggest metal ligand. Around (1600-1700 cm⁻¹) could be C=O or C=N stretches (Common in ligand). Around 3300cm⁻¹ indicate O-H ,N-H (amine ligand ,water coordination). Figure 5

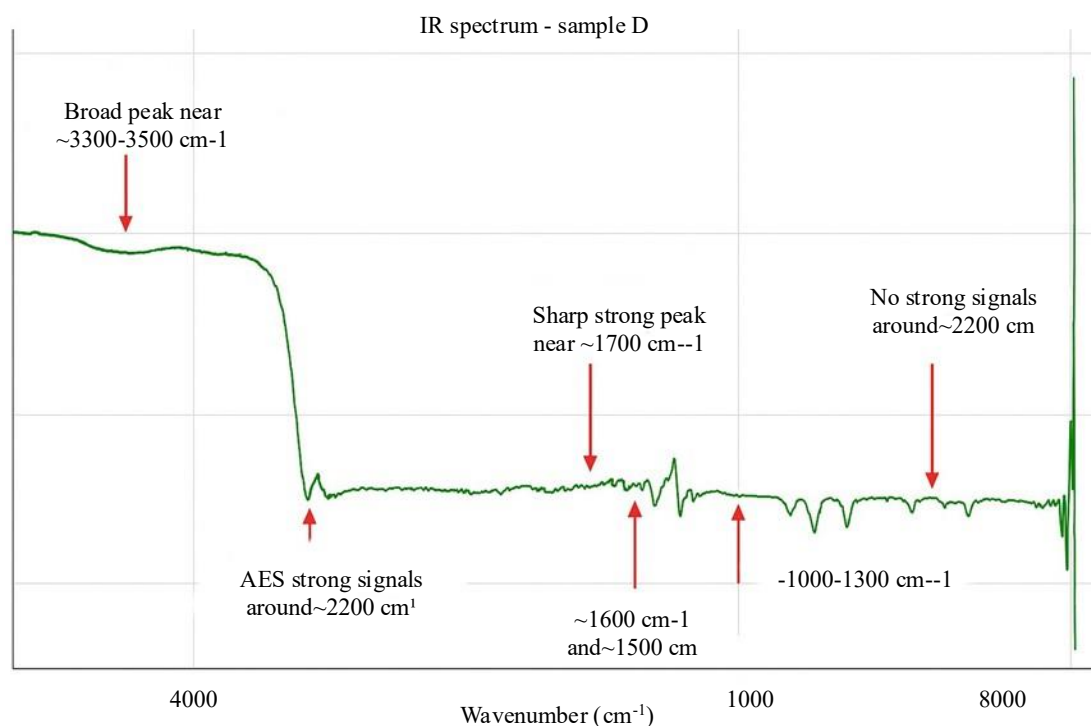


Figure 4. IR spectrum of Cu(II) metal complex (ML_2).

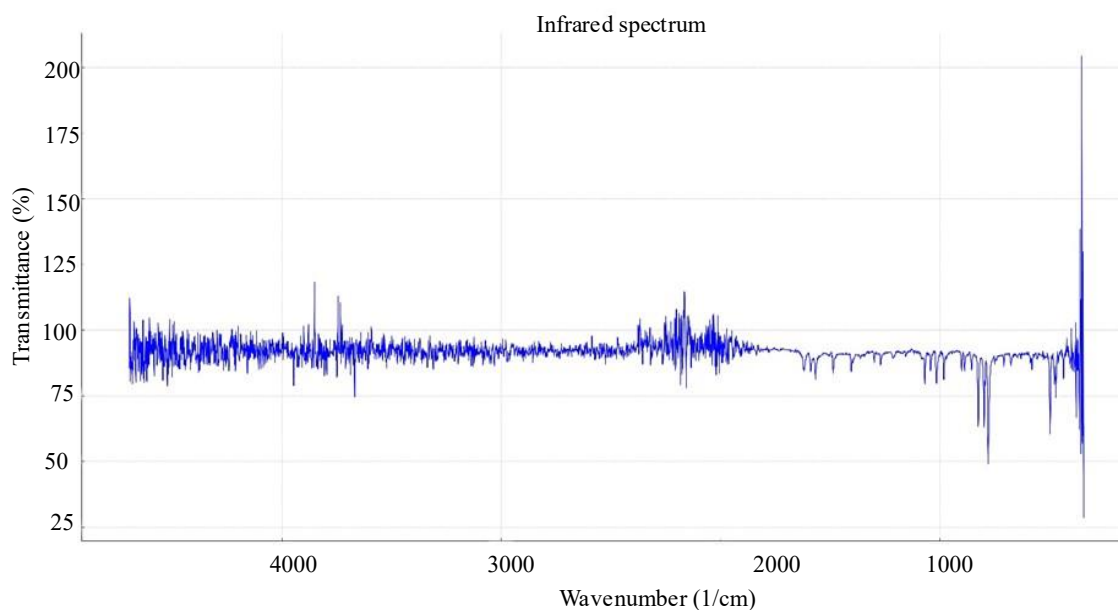


Figure 5. IR spectrum of Zn (II) metal complex (ML_2).

ANTIBACTERIAL ACTIVITY

The antibacterial activity [23] of reported compounds had been evaluated by using the test organism like *E. coli*, *Pseudomonas* and *B.sereus* with help of plate diffusion assay method. Schiff bases, known for their versatile biological properties, often exhibit significant antimicrobial effects due to their imine ($-C=N-$) functional group. When Schiff bases form metal complexes, their biological activity is often enhanced through improved stability and cell permeability. Testing these compounds for antimicrobial activity helps in evaluating their potential as new therapeutic agents. Such studies are crucial for developing novel drugs to combat resistant microbial strains. Both nickel complex and copper complex were tested for antimicrobial activity Table 1

Table 1. Schiff Base and Metal Complex.

Schiff Base and Metal Complex	E.coli	Pseudomonas	B. sereus
SCHIFF BASE(o-nitro benzaldehyde & α -naphthylamine)	NO ACTIVITY	NO ACTIVITY	NO ACTIVITY
Ni(II) Metal complex	NO ACTIVITY	NO ACTIVITY	NO ACTIVITY
SCHIFF BASE (p-anisaldehyde & α -naphthylamine)	+ 10mm_	NO ACTIVITY	NO ACTIVITY
Cu(II) Metal complex	NO ACTIVITY	NO ACTIVITY	NO ACTIVITY

The results suggest that complexation with Cu(II) enhanced the antimicrobial potential of the ligand. The observed activity against E. coli highlights the possible bioactive nature of the copper complex, which could be explored further for medicinal or pharmaceutical applications. Figure 6-8

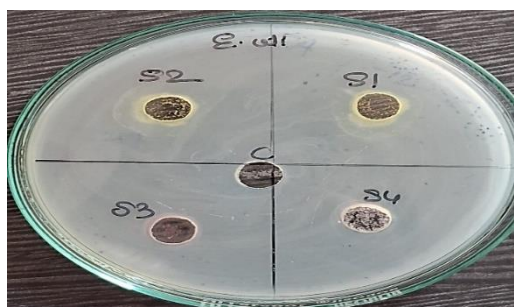


Figure 6. Sample 1 and 2 is schiff base and nickel metal complex. sample 3 and 4 is schiff base and copper metal complex of e.coli.

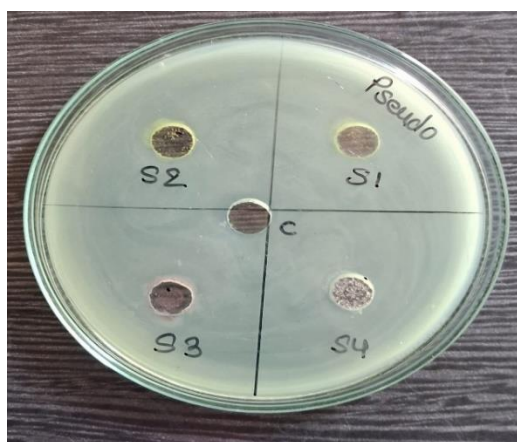


Figure 7. Sample 1 and 2 is schiff base and nickel metal complex. sample 3 and 4 is schiff base and copper metal complex of pseudomonas.

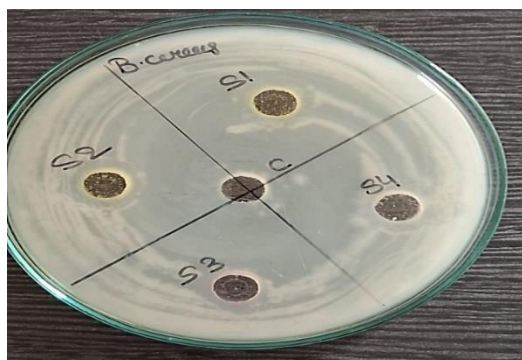


Figure 8. Sample 1 and 2 is schiff base and nickel metal complex. sample 3 and 4 is schiff base and copper metal complex of b.cereus.

CONCLUSION

The study successfully synthesized Schiff bases and their Ni(II), Cu(II), and Zn(II) complexes. FTIR analysis confirmed the coordination between metal ions and Schiff bases through characteristic shifts in functional group vibrations. Antimicrobial testing showed that the Cu(II) complex exhibited mild activity against *E. coli*, while other samples showed no significant effect. This highlights the potential of metal complexation in enhancing biological properties. Further modifications could improve the antimicrobial efficacy of such complexes.

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