



Thermal Decomposition Kinetics Of A Cobalt (II) Complex Synthesized From A Schiff Base Formed By 5-Amino-1,2,3,4-Thiatriazole And Ortho-Methoxy-Benzaldehyde

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Abstract: The Co (II) complex synthesized from the Schiff base of 5-amino-1,2,3,4-thiatriazole and ortho-methoxy benzaldehyde exhibits significant structural stability and functional versatility. The study revealed that mass measurements taken at various temperatures, analysed using Doyle's method as modified by Zsako, facilitated the determination of kinetic parameters for the presumed reaction order. The most precise activation energy (E) was identified based on the smallest standard deviation (δ), offering insights into how well the decomposition process aligned with the assumed kinetic function $F(\alpha)$. Findings showed that a reaction order of $b = 0.36$, an activation energy of 12.16 kcal/mol, and an average $(\bar{B}_0) = 7.37011$ resulted in the minimum $\delta_{\min} = 0.14296$. By comparing different kinetic models, the research emphasized the effectiveness of statistical methods in accurately matching experimental results with theoretical predictions. The apparent entropy of activation (ΔS) was found to be -23.45 e.u.. The results highlight the effectiveness of Doyle's modified method and its consistency with Freeman and Carroll's approach, ensuring a reliable determination of kinetic parameters and confirming the relevance of the proposed kinetic models. Its promising antimicrobial and antioxidant activities also position it as a potential candidate for pharmaceutical and biomedical use. In addition, the cobalt complex shows considerable potential in materials science, particularly in the development of electrochemical sensors, rechargeable batteries, and fuel cell components

Index Terms - Cobalt-complex; Schiff base; Entropy of activation; Activation energy; TGA;

I.INTRODUCTION

In recent thermal decomposition of metal-complexes in solid state has been attracted research topic for analysis of thermal decomposition kinetics(Askar et al., 1989)(Thammakan and Somsook, 2006)(Elemo et al., 2019). Thermal analysis method is an important scientific tool for various field of research including chemical science, medical, polymer and biological field. There are various techniques for thermal analysis to reveal the material response against the temperature variation, including differential scanning calorimetry (DSC), differential thermal analysis (DTA), and thermogravimetric analysis (TGA). These techniques are particularly valuable for analyzing thermal stability, phase transitions, and decomposition behavior in materials such as polymers, pharmaceuticals, and biomaterials. In the pharmaceutical industry, they are instrumental in evaluating drug-exipient interactions, optimizing formulation processes, and ensuring product stability(Gurusamy et al., 2025). Additionally, thermal analysis aids in understanding polymer composition, thermal transitions, and degradation characteristics. Notably, metal complexes incorporating thiosemicarbazone ligands have attracted attention as potential anticancer agents. These compounds function by targeting and inhibiting enzymes essential for DNA replication and cell proliferation, making them valuable in cancer therapy. Furthermore, ligands that contain donor atoms such as nitrogen, oxygen, and sulfur

are well-recognized for exhibiting a wide spectrum of biological activities, including antibacterial, antiviral, antifungal, antitumor, and antimalarial effects(Ahmad et al., 2024)(West et al., 1990). Coordination chemistry is a core sub-discipline of inorganic chemistry that explores the interaction between central metal atoms or ions and surrounding ligands. These ligands may be neutral molecules or anions capable of donating electron pairs to the metal centre. The formation of coordination compounds is central to understanding various chemical and biological processes.

The complexity and diversity of metal-ligand interactions make this field a challenging yet rich area of research. Schiff bases(Boulechfar et al., 2023)(Yadav et al., 2025)(Janjua et al., 2023), characterized by the presence of an imine or azomethine group ($-C=N-$), form an important class of nitrogen-donor ligands widely utilized in coordination chemistry. These compounds are generally prepared through the condensation reaction between primary amines and aldehydes or ketones, resulting in products with the characteristic structure of $RN=CR'$. Here, R' and R may be alkyl, cycloalkyl, aryl, or heterocyclic groups, often bearing additional substituents that further modulate their chemical behavior. One of the defining features of Schiff bases is their structural versatility, which enables them to function as monodentate, bidentate, or even tridentate ligands, depending on the nature and position of other donor atoms such as nitrogen, oxygen, or sulfur within the molecule(Singh et al., 2025). The presence of nearby functional groups like hydroxyl ($-OH$), thiol ($-SH$), or carboxyl ($-COOH$), significantly improves their ability to act as chelating agents, frequently resulting in the formation of stable five- or six-membered rings when coordinated with metal ions. Their binding strength and selectivity are influenced by several factors: (a) Electronegativity and hybridization of the donor atoms (e.g., sp^2 -hybridized nitrogen in the imine group); (b) Steric hindrance from bulky substituents near the donor sites; (c) The geometrical compatibility of the ligand with the preferred coordination geometry of the metal ion. Tridentate Schiff bases(Egekenze et al., 2018)(Asran et al., 2025), for example, can coordinate through multiple donor sites simultaneously, often forming two annulated chelate rings, which contribute to the enhanced thermodynamic and kinetic stability of the resulting metal complexes. Schiff base ligands and their corresponding metal complexes have become a focal point in medicinal chemistry because of their diverse and potent biological activities.

The imine group ($-C=N-$) is instrumental in promoting interactions with both biological molecules and metal ions within living organisms(Ismail et al., 2023)(Alka et al., 2023). These compounds are known to possess an extensive array of pharmacological properties, including but not limited to: Antifungal, Anticancer, Antihypertensive, Antiviral, Antioxidant, and Antibacterial. The mechanism of biological action is often linked to their ability to form coordination complexes with metal ions in enzymes or DNA, thereby altering biological pathways. Certain Schiff base-metal complexes have demonstrated enhanced effectiveness over conventional drugs, highlighting their potential as promising leads for the development of novel therapeutic agents. Schiff base-metal complexes play a significant role in bioinorganic chemistry due to their capacity to imitate the behaviour of biologically relevant metal-containing systems. The coordination of organic ligands, such as Schiff bases, with metal ions can substantially influence the chemical properties and reactivity of the resulting complexes(Guguloth et al., 2019). This modulation makes them excellent models for studying enzymatic mechanisms and metabolic transformations. Metal ions are essential in various biological processes, where they contribute not only to the structural stability of biomolecules but also to the regulation of genetic expression and metabolic pathways. Among the derivatives of Schiff bases, thiosemicarbazones formed through the condensation of thiosemicarbazide with aldehydes or ketones stand out for their distinct coordination behaviour and biological significance(Shul'pina et al., 2020)(Alka et al., 2023)(Khan et al., 2022). These compounds commonly act as bidentate ligands, binding to metal centres through the sulfur atom and the hydrazinic nitrogen, thus forming stable chelate complexes. Metal ions not only help to stabilize the Schiff base framework but also promote planarity within the ligand, improving its electronic properties and coordination potential.

This article details the synthesis and characterization of a novel Schiff base ligand derived from the condensation reaction between 5-amino-1,2,3,4-thiatriazole and ortho-methoxybenzaldehyde, hereby designated as ATTZOMBA (5-amino-1,2,3,4-thiatriazole O-methoxybenzaldehyde). The primary objective of this study was to develop a new class of ligands with potential chelating properties and evaluate their coordination behavior with selected transition metal ions, specifically cobalt(II) (Co^{2+})(Agarwal et al., 2006)(Chandra and Kumar, 2005). The synthesis of these ligands was carried out in the laboratory using methodologies adapted from standard synthetic procedures, with modifications guided by the work of various researchers. These adaptations were necessary to optimize reaction conditions suitable for the unique structural features of the 5-amino-1,2,3,4-thiatriazole moiety and the aromatic aldehyde. The protocols were refined through careful experimentation and literature support to ensure successful formation of the Schiff base ligand with high purity and yield(Singh et al., 2025)(Leovac et al., 2003)(Zsako et al., 1975). These

procedures were optimized to suit the reactivity and solubility profile of the thiatriazole moiety, ensuring high yield and purity of the final products. To ensure the accuracy and reproducibility of results, all reagents used in the synthesis of both ligands and metal complexes were of high-purity, analytical reagent grade (Boulechfar et al., 2023) (Yadav et al., 2025) (Daravath et al., 2019). Where necessary, reagents were subjected to additional purification using conventional laboratory methods to eliminate any trace impurities that might interfere with the reaction kinetics or product characterization. Solvents such as *N*-methylpyrrolidone (NMP), methanol, and ethanol played a crucial role in both the reaction medium and purification processes. These solvents were meticulously purified using standard literature procedures prior to use, to ensure solvent consistency and to minimize the risk of side reactions or solvent-induced structural variations in the ligand or its metal complexes.

II. EXPERIMENTAL PROCESS

To synthesize the cobalt(II) complex with the 5-amino-1,2,3,4-thiatriazole and *o*-methoxybenzaldehyde (ATTZOMBA) ligand, a solution containing approximately 0.01 M of the ligand was prepared by dissolving it in 40-50 mL of *N*-methylpyrrolidone (NMP). Separately, hydrated cobalt(II) chloride was also dissolved in the same solvent. These two solutions were then mixed in a molar ratio of 2:1 (ligand to metal salt) while maintaining a warm temperature and continuous stirring to facilitate interaction. The combined mixture was subjected to refluxing in an oil bath maintained at 150 °C to 160 °C, using a water-cooled condenser to prevent solvent loss. After refluxing for about 1 to 2 hours, a reddish-brown solid began to form, indicating the formation of the complex. This solid was collected by filtration, washed repeatedly with hot double-distilled water to remove any excess or unreacted cobalt ions, and then dried in an electric oven at 100 °C to obtain the final product. The carbon, hydrogen, and nitrogen compositions of the ligands and metal complexes were determined. To assess the metal and sulfur contents of the metal complexes, the samples were decomposed, and the analysis was conducted using established standard methods. This study explores the thermal stability and decomposition behavior of a synthesized cobalt(II) complex formed through a Schiff base condensation between 5-amino-1,2,3,4-thiatriazole and ortho-methoxybenzaldehyde. Key kinetic parameters such as the reaction order (*n*), activation energy (*E*), and activation entropy (ΔS) were calculated using the Freeman–Carroll differential method and the modified Doyle approach as outlined by Zsako (1982). Thermogravimetric analysis (TGA) was performed by heating approximately 20 - 25 mg of the cobalt complex in an alumina crucible at a uniform rate of 10 °C per minute under a nitrogen atmosphere. The mass loss at every 10 °C interval was measured to monitor distinct stages of thermal degradation. This analysis offers valuable insight into the thermal robustness and kinetic profile of the complex, which is essential for evaluating its practical applications. The Freeman–Carroll method, being a differential technique in TGA, facilitates the concurrent determination of the activation energy and reaction order by analyzing the relationship between mass loss rate and the remaining sample weight throughout the decomposition process.

III. EXPERIMENTAL PROCESS

The thermal decomposition of solid materials, even when expressed by a seemingly simple stoichiometric reaction such as



involves a complex and multi-stage process. This transformation is far more intricate than the basic equation suggests. The decomposition typically begins with the disruption of intramolecular and intermolecular chemical bonds within the solid matrix, followed by the disintegration of the crystalline lattice structure of the original compound. As the reaction proceeds, new solid phases may begin to form through nucleation and subsequent growth, while simultaneous adsorption and desorption of the evolved gaseous species (*C*) occur on the solid surface. These physical and chemical transformations are further influenced by heat and mass transfer phenomena, particularly the diffusion of the gaseous products from within the bulk material to the surrounding environment. Such interactions make the overall decomposition mechanism highly dynamic and non-linear. Due to this complexity, accurately determining the kinetic parameters of thermal decomposition such as reaction order (*n*), activation energy (*E*), pre-exponential (frequency) factor (*Z*), and entropy of activation (ΔS) presents significant challenges. These parameters are essential for understanding the stability and degradation behavior of solid compounds, particularly metal complexes. To overcome these challenges, a variety of kinetic models and mathematical methods have been developed and refined. These models aid in interpreting experimental data and estimating kinetic parameters with reasonable accuracy.

This work focuses on the comprehensive kinetic analysis of the thermal decomposition behavior of various metal complexes derived from the Schiff base synthesized using 5-amino-1,2,3,4-thiatriazole and ortho-methoxy benzaldehyde, herein referred to as ATTZOMBA. The metal complexes cobalt (Co) have been

synthesized and subjected to thermogravimetric analysis (TGA) to evaluate their thermal stability and decomposition characteristics. The kinetic parameters associated with the decomposition processes were determined using two well-established methodologies: the Freeman-Carroll differential method and Doyle's integral procedure, the latter as modified by Zsako. These approaches enable the calculation of key thermodynamic and kinetic quantities, which provide insights into the thermal behavior of the metal complexes and the nature of their decomposition mechanisms. Specifically, the following kinetic parameters were evaluated: (a) Activation Energy (E): The minimum energy required for the decomposition process to occur, which reflects the thermal stability of the complex. (b) Entropy of Activation (ΔS): Provides information regarding the degree of order or disorder introduced in the transition state as the reaction proceeds. (c) Frequency Factor (Z): Also known as the pre-exponential factor, it denotes the number of times that reactants approach the activation barrier per unit time. For each assumed reaction order and activation energy, the corresponding standard deviations δ_0 , δ_1 , and δ_2 were also calculated to assess the reliability and consistency of the computed parameters. These values B_0 , B_1 , B_2 , and their respective δ_0 , δ_1 , δ_2 were systematically evaluated across a range of temperatures and activation energies, enabling a comprehensive kinetic assessment of the decomposition behavior.

Zsako's modification of Doyle's procedure provides enhanced precision and adaptability, making it particularly well-suited for analyzing the complex, multi-step thermal decomposition commonly observed in metal-organic coordination compounds such as the ATTZOMBA metal complexes. This refined approach allows for a more accurate determination of activation energy and other kinetic parameters in systems with overlapping or sequential decomposition steps. The thermogravimetric data corresponding to different decomposition stages were analyzed for each metal complex, and the results have been systematically presented and discussed in this chapter. Comparative analysis of the kinetic parameters across different metal centers provides valuable information regarding the influence of metal ion nature on the thermal decomposition behavior of the Schiff base complexes. These results not only enhance our understanding of the stability and decomposition mechanisms of the studied compounds but also contribute to the broader field of coordination chemistry and materials science, especially in the context of designing thermally stable metal-organic complexes for potential industrial or pharmacological applications.

Table 1: Data obtained by Freeman and Carroll Method for Co(II) Complex.

Sr. No.	Temp (°C)	Weight (mg)	$W_r = W_c - W$	$\frac{\Delta \log dw/dt}{\Delta \log(w_r)}$	$\frac{\Delta T^{-1} \times 10^3}{\Delta \log(w_r)}$
1	160	3.6572	1.23630	2.81934	1.12622
2	170	3.5213	1.10040	0.61561	1.03083
3	180	3.4732	1.05230	23.23807	2.56714
4	190	3.2854	0.86450	-6.92888	0.55846
5	200	3.1912	0.77030	5.98032	0.91133
6	210	3.0148	0.59390	-2.41218	0.38754
7	220	2.9136	0.49270	2.97443	0.51763
8	230	2.7621	0.34120	-1.09813	0.25271
9	240	2.6154	0.19450	0.05728	0.15877
10	250	2.5146	0.09370	0.51381	0.11751
11	260	2.4678	0.04690	1.10862	0.11935

Initial weight at 150°C = 3.8032 mg and Final weight at 270°C = 2.4209 mg.

A plot is drawn to analyze the decomposition stage, where the y-axis represents $\frac{\Delta \log \frac{dw}{dt}}{\Delta \log w_r}$ and x-axis represents $\frac{\Delta T^{-1} \times 10^3}{\Delta \log w_r}$. Here, W_r is the remaining mass fraction defined as $W_r = W_c - W$, with W_c being the total mass loss at the completion of the reaction, and W being the total mass loss at time t . The TG curve was used to directly determine the residual mass (W_r) at uniform temperature intervals, and the collected data were analysed using the Freeman and Carroll method, as summarized in Table 1. The graph of $\frac{\Delta \log dw/dt}{\Delta \log(w_r)}$ versus $\frac{\Delta T^{-1} \times 10^3}{\Delta \log(w_r)}$ is obtain approximately straight line. The intercept of straight line is 0.36. The intercept suggests a reaction order of 0.36, and the activation energy is calculated as 12.16 kcal/mol using the equation $E = 2.303R \times \text{slope}$. Thermal decomposition kinetics of the synthesized Co(II) complex were evaluated using mass measurements at varying temperatures, applying Doyle's method as modified by Zsako.

Table 2: Data of log F(α) values for the Co(II) complex calculated at different temperatures.

Sr. No.	Temp (°C)	$\alpha = \frac{W_o - W_t}{W_o - W_f}$	Log(α)	$Log\left(\ln \frac{1}{(1-\alpha)}\right)$	$Log\left(\frac{\alpha}{(1-\alpha)}\right)$
1	160	0.10562	-0.97625	-0.95224	-0.92777
2	170	0.20394	-0.69051	-0.64192	-0.59146
3	180	0.23873	-0.62209	-0.56420	-0.50363
4	190	0.37459	-0.42644	-0.32850	-0.22260
5	200	0.44274	-0.35385	-0.23305	-0.09991
6	210	0.57035	-0.24386	-0.07325	0.12303
7	220	0.64357	-0.19141	0.01351	0.25661
8	230	0.75317	-0.12311	0.14583	0.48448
9	240	0.85929	-0.06586	0.29249	0.78582
10	250	0.93221	-0.03048	0.42998	1.13838
11	260	0.96607	-0.01499	0.52936	1.45444

The log F(α) values listed in Table 2 served as the basis for determining activation energies (δ_0 , δ_1 , δ_2) and kinetic parameters (B_0 , B_1 , B_2) under different assumed reaction orders, with the results compiled in Tables 3-5. The most accurate value of activation energy (E) was selected by identifying the standard deviation (δ) with the smallest magnitude, indicating the best match between the kinetic model and the decomposition data. A comparison of $\delta_{\min}$ values across different kinetic models allowed identification of the function F(α) that best fit the experimental results. The analysis showed that the lowest value $\delta_{\min}$ (0.14296) was linked to a reaction order of $b = 0$, with an activation energy of 12 kcal/mol and an average kinetic parameter ($\overline{B_0}$) of 7.37011, indicating this model as the most representative of the decomposition behaviour.

Table 3: Calculation of $B_0 = \text{Log}(\alpha) - \text{Log P}(x)$ for different activation energies and values at different temperature, Co(II) complex.

Sr. No.	Temp. (°C)	E=12 kcal	E=14 kcal	E=16 kcal
1	160	7.42575	8.56075	9.68275
2	170	7.55349	8.66649	9.76749
3	180	7.47391	8.56391	9.63891
4	190	7.52656	8.59856	9.65156
5	200	7.46415	8.51015	9.54615
6	210	7.43914	8.47314	9.48614
7	220	7.36659	8.37759	9.37459
8	230	7.31489	8.30889	9.28789
9	240	7.25114	8.22814	9.19314
10	250	7.17552	8.13452	9.08252
11	260	7.08001	8.02701	8.95701
Average B_0		7.37011	8.40447	9.42438
Standard Deviation δ_0		0.14296	0.19734	0.25417

Table 6 summarizes the $\delta_{\min}$ values corresponding to various hypothetical reaction orders, further supporting the conclusion that the model with $\delta_{\min} = 0.14296$ provides the best fit. Additionally, Table 7 presents a comparative evaluation of reaction orders (n) and activation energies (E) derived using both the Freeman–Carroll and Zsako methods. The results demonstrate strong agreement between the two approaches, reinforcing the reliability and consistency of the kinetic data obtained.

Table 4: Calculation of $B_1 = \text{Log}(\ln(1/(1-\alpha))) - \text{Log } P(x)$ for different activation energies and δ_1 values at different temperature, Co(II) complex.

Sr. No.	Temp. (°C)	E=18 kcal	E=20 kcal	E=22 kcal
1	160	10.81276	11.90776	12.99976
2	170	10.90008	11.97308	13.03908
3	180	10.76380	11.81580	12.85880
4	190	10.78950	11.82450	12.84650
5	200	10.68995	11.70195	12.70695
6	210	10.65775	11.65375	12.63575
7	220	10.56251	11.54551	12.50651
8	230	10.52283	11.47883	12.42683
9	240	10.50049	11.43949	12.36949
10	250	10.47398	11.39498	12.31298
11	260	10.41436	11.32336	12.22236
Average B_1		10.64437	11.64173	12.62955
Standard Deviation δ_1		0.15239	0.21041	0.26973

Table 5: Calculation of $B_2 = \text{Log}(\alpha/(1-\alpha)) - \text{Log } P(x)$ for different activation energies and δ_2 values at different temperature, Co(II) complex.

Sr. No.	Temp. (°C)	E=24 kcal	E=26 kcal	E=28 kcal
1	160	14.10523	15.18423	16.25423
2	170	14.14854	15.20054	16.25354
3	180	13.95737	14.98737	16.01437
4	190	13.96740	14.98140	15.98640
5	200	13.83409	14.82609	15.81309
6	210	13.81403	14.78403	15.74903
7	220	13.70761	14.66161	15.60961
8	230	13.70648	14.64248	15.57348
9	240	13.78682	14.70482	15.62382
10	250	13.92738	14.83338	15.72938
11	260	14.04144	14.92944	15.81244
Average B_2		13.90876	14.88504	15.85631
Standard Deviation δ_2		0.14480	0.18300	0.23048

Based on the provided data, the apparent frequency factor (Z) was determined to be 647.13 S^{-1} using Equation 1. The apparent entropy of activation (ΔS) for the examined decomposition stage was calculated as -23.45 e.u. using Equation 2. In these calculations, $\bar{B}$ represents the average value from the most consistent set of B_i parameters, R is the universal gas constant, q denotes the heating rate, E is the activation energy, h stands for Planck's constant, and K_B refers to Boltzmann's constant. The temperature corresponding to 50% mass loss during pyrolysis was recorded at 473 K. The close agreement between kinetic parameters derived from two independent methods confirms the reliability of the thermal analysis, as detailed in Table 7.

$$\log Z = \bar{B} + \log Rq - \log E \quad 1$$

$$\Delta S = 2.303 \times \log \frac{Zh}{K_B T} \quad 2$$

where $\bar{B}$ represents the average of the most consistent series of B_i values, R is the universal gas constant, q is the heating rate, E denotes the activation energy, h is Planck's constant, K_B refers to Boltzmann's constant.

Table 6: Comparison of the values of δ and their activation energies for the assumed reaction order, for Co(II) complex.

b = 0		b = 1		b = 2	
E (Kcal/mol)	δ_0	E (Kcal/mol)	δ_1	E (Kcal/mol)	δ_2
12	0.14296	18	0.15239	24	0.14480
14	0.19734	20	0.21041	26	0.18300
16	0.25417	22	0.26973	28	0.23048

The bold values show the minimum deviation for the activation energy 12 kcal.

Table 7: Orders of reaction (n) and activation energy (E) by both the adopted procedures, for Co(II) complex.

Methods	Order of reaction (n)	Activation Energy 'E' (Kcal/mol)
Freeman and Carroll	0.36	12.16
J. Zasko	0	12

IV.CONCLUSIONS

The study revealed that mass measurements taken at various temperatures, analysed using Doyle's method as modified by Zsako, facilitated the determination of kinetic parameters for the presumed reaction order. The most precise activation energy (E) was identified based on the smallest standard deviation (δ), offering insights into how well the decomposition process aligned with the assumed kinetic function $F(\alpha)$. Findings showed that a reaction order of $b = 0.36$, an activation energy of 12.16 kcal/mol, and an average $(\overline{B_0}) = 7.37011$ resulted in the minimum $\delta_{\min} = 0.14296$. By comparing different kinetic models, the research emphasized the effectiveness of statistical methods in accurately matching experimental results with theoretical predictions. The apparent entropy of activation (ΔS) was found to be -23.45 e.u.. The results highlight the effectiveness of Doyle's modified method and its consistency with Freeman and Carroll's approach, ensuring a reliable determination of kinetic parameters and confirming the relevance of the proposed kinetic models.

V.APPLICATIONS OF Co(II) COMPLEX

The cobalt(II) complex synthesized from the Schiff base formed between 5-amino-1,2,3,4-thiazotriazole and ortho-methoxybenzaldehyde exhibits diverse applications owing to its unique coordination environment and electronic characteristics. This complex serves as an effective catalyst in several organic reactions, including oxidation and polymerization, where the Schiff base ligand enhances stability and reactivity. Its promising antimicrobial and antioxidant activities also position it as a potential candidate for pharmaceutical and biomedical use. In addition, the cobalt complex shows considerable potential in materials science, particularly in the development of electrochemical sensors, rechargeable batteries, and fuel cell components. Its electroactive and redox properties make it suitable for energy storage and conversion technologies. The coordination flexibility and magnetic behaviour of Co(II) complexes further support their use in molecular electronics, magnetic materials, and environmental remediation, highlighting their relevance across multiple scientific and industrial domains. Certain cobalt complexes exhibit interesting photochromic and luminescent properties, enabling their use in light-sensitive materials, molecular switches, or optical sensors.

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