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Review Article

# Synthesis, Reactivity, Biomedical and Allied Applications of Schiff Base Derivatives of Transition Metals

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## Abstract

The review features primary properties and natural investigations of change metal complexes got from Schiff base. Advancement of another chemotherapeutic Schiff bases and their metal complexes is presently drawing in the consideration of restorative scientific experts. This audit assembles instances of the most encouraging applied Schiff bases and their buildings in various biomedical and united regions.

**Keywords:** Schiff base, Metal Complexes. Antimicrobial activity, Antitumor activity

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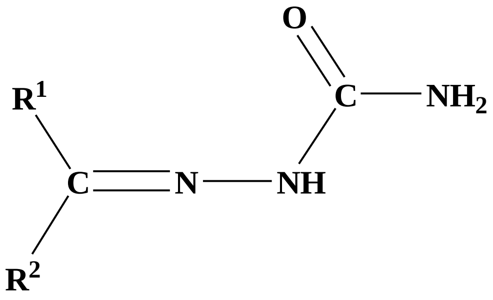
## Introduction

Transition metal buildings of Schiff bases integrated from build-up of an amine with carbonyl mixtures are generally utilized for modern purposes like catalysts, pigments and dyes, intermediates in natural union, polymer stabilizers, and erosion inhibitors. For plan and advancement of different bioactive mixtures, Schiff bases conveying imine or azomethine (−C = N–) utilitarian gathering, are flexible pharmacophores. The natural action of the change metal buildings got from the Schiff base ligands has been broadly examined.

## Schiff - Bases

Schiff-bases have assumed a significant part in the advancement of coordination science as they promptly structure stable edifices with the majority of the main group, change and later progress metals. Schiff bases and their primary analogs, as ligating compounds containing non-cyclic and cyclic imine bonds, are vital in current coordination chemistry [1].

A Schiff base is nitrogen simple of an aldehyde or ketone in which the C=O group is supplanted by a >C=N group. It is typically framed by the buildup of RCHO or RR'C=O with an essential amine as indicated by the accompanying scheme 1:



Semicarbazone
Where, R may be an alkyl or an aryl group.
**Scheme 1** Synthesis of Schiff base

Schiff bases which hold aryl substituents are considerably steadier and all the more promptly integrated, while those that accommodate alkyl substituents are promptly incorporated, however those which hold alkyl substituents are moderately temperamental. Schiff bases of aliphatic aldehydes are generally flimsy and promptly polymerizable [2], while those of fragrant aldehydes having successful formation are more stable [3]. The stereochemistry and electronic construction of chelates decide numerous properties, reactivity and capacity to shape adducts. These functionalities are significant for understanding numerous synergists cycles and wonders happening in living organisms [4]. In science, Schiff bases track down an adaptable utilize some of them are the fundamental units in specific colors, though; some are utilized as fluid precious stones.

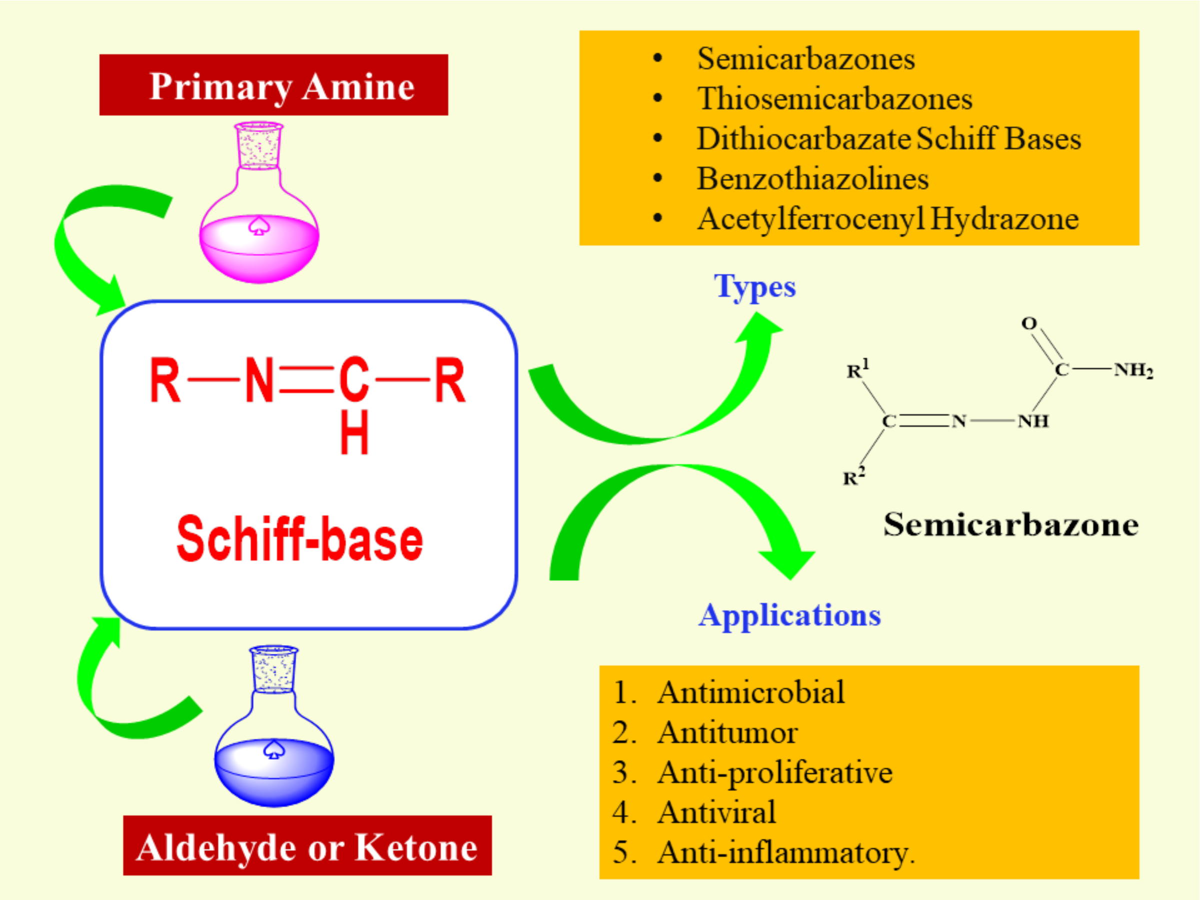


**Figure 1.** Schematic representation of Schiff bases and their applications.

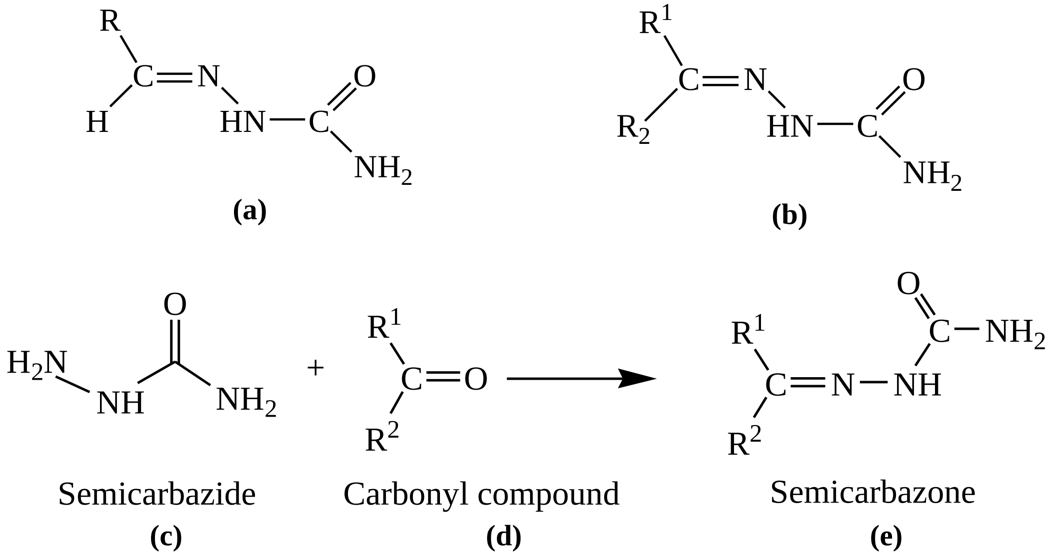
Numerous naturally significant Schiff bases have been accounted for in the writing having, antibacterial [5], antifungal, antimicrobial [6], anticonvulsant, hostile to HIV, mitigating and antitumor [7] exercises (**Figure 1**). Lately, the coordination conduct of organometallic mixtures of Schiff bases with O, S, and N containing ligands has gotten incredible consideration as a result of their natural property. Because of the more prominent adaptability and different primary parts of the Schiff bases, mixtures of these have been integrated and their complexation conduct has been concentrated by the different workers [8].

Chang et al. [9] incorporated and portrayed and clarify the gem construction of trinuclear Ni(II) complex trinuclear with N, N'- Bis(salicylidene) - 1,3-diiminopropane a Schiff base ligand. As of late Chohan orchestrated and described the Schiff base-got from sulfonamides and their cobalt (II), copper (II), nickel (II) and zinc (II) buildings and all mixtures showed cytotoxic properties. The X-beam design of 4-[(2-hydroxybenzylidene) amino] benzene sulfonamide is likewise detailed. Han et al.[10] blended and described two progress metal (Zinc, Copper) buildings with a Schiff base (salicylideneglycine) and 1,10-phenanthroline: $(C_9H_7NO_3)Zn(C_{12}H_8N_2)(H_2O)$ (1) and $(C_9H_7NO_3)Cu(C_{12}H_8N_2)$ (2) including gem structures, otherworldly portrayal, thermogravimetric investigations and quantum science computations. The SOD mimetic movement of buildings researched by NBT-enlightenment. Complex 2 has preferred superoxide dismutase–like action over [1].

### *Semicarbazones*

As indicated by the IUPAC proposals for the terminology of natural mixtures, subordinates of semi carbazide of the sorts (a) and (b) of the **Figure 2**, which will be which are typically gotten by the buildup of semicarbazide with appropriate aldehyde and ketones, might be named by adding the class name 'semicarbazone' after the name of the consolidated RCHO or RR'C=O.

Beraldo et al. [11] prepared vanadium complexes with 2-pyridineformamide thiosemicarbazone. Reactions of $VOCl_2$ with 2-pyridineformamide thiosemicarbazone ($H_2Am4DH$) and its N(4)-methyl ($H_2Am_4Me$), N(4)-ethyl ($H_2Am_4Et$) and N(4)-phenyl ($H_2Am_4Ph$) derivatives give the required products. These complexes prohibit glycerol release in a same way to that observed with insulin but exhibited a low enhancing effect on glucose uptake by rat adipocytes. The crystal and molecular structures of the complexes were also determined (**Figure 3**)



(a) (b)

Semicarbazide (c) Carbonyl compound (d) Semicarbazone (e)

**Figure 2.** Derivatives of semi carbazide.

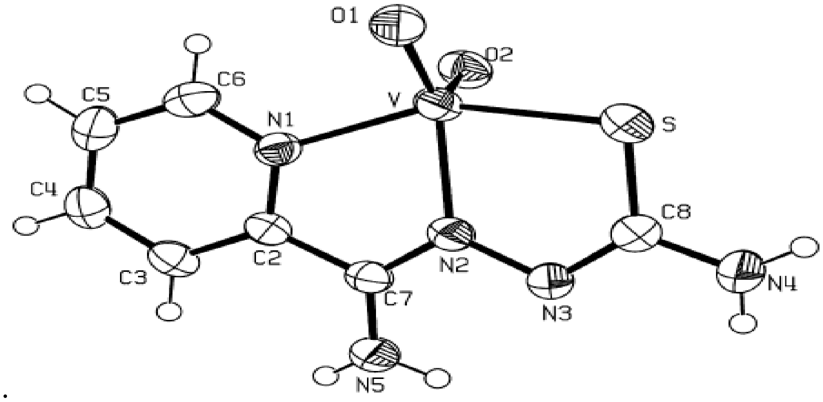


**Figure 3.** Molecular plot of $[VO_2(2Am_4DH)]$.

***Thiosemicarbazones***

The science of thiosemicarbazones has gotten impressive consideration taking into account their variable holding modes, promising organic ramifications, underlying variety, and particle detecting capacity. These are concentrated broadly because of their adaptability, their selectivity and affectability towards the focal metal molecule, underlying and likenesses with regular natural substances.

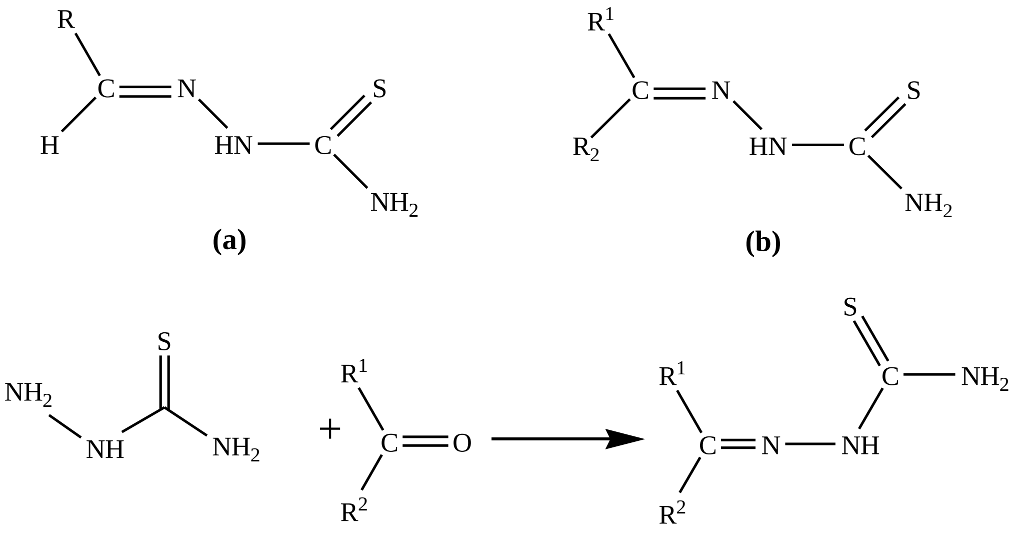
As indicated by the IUPAC suggestions for the terminology of natural mixtures, subsidiaries of thiosemicarbazide of the kinds (a) and (b) of **Figure 4** which are generally gotten by the buildup of thiosemicarbazide with reasonable aldehyde and ketones, might be named by adding the class name 'thiosemicarbazone' later the name of the condensed RCHO or RR’C=O.

Thiosemicarbazones are encouraging particles in coordination science due to their pharmacological functionalities [12] which incorporate prominently their antiparasital, antibacterial and antitumor exercises.

As respects organic ramifications, thiosemicarbazone edifices have been seriously examined for antiviral, anticancer, antitumoral, antimicrobial, ant amoebic, and mitigating exercises. The inhibitory activity is credited because of their chelating properties [13].

Thiosemicarbazones have a wide scope of clinical properties which have been accounted for by different laborers to be dynamic against infection, psoriasis, stiffness, trypanosomiasis and coccidiosis. Thiosemicarbazones are extremely encouraging atoms in coordination science due to their pharmacological properties.

Pedrido [14] revealed the Ag thiosemicarbazone buildings with the response of silver acetic acid derivation with a phosphinothiosemicarbazone ligand, HLPPh (**Figure 5**), yielded the tetranuclear silver compound $[Ag_4(LPPh)_4]$.2MeOH (1), which after recrystallization brings about the cocrystallization of two distinctive silver groups, $[Ag_4(LPPh)_4]$a-$[Ag_4(LPPh)_4]$b · 8MeOH (2). The components associated with the get together of tetranuclear compounds gotten from thiosemicarbazone ligands and the underlying contrasts between the two groups are examined. Furthermore, HLPPh and complex 1 show photoluminescence in arrangement at room temperature.



(a) (b)

Thiosemicarbazide Carbonyl compound Thiosemicarbazone

**Figure 4** Derivatives of thiosemicarbazide

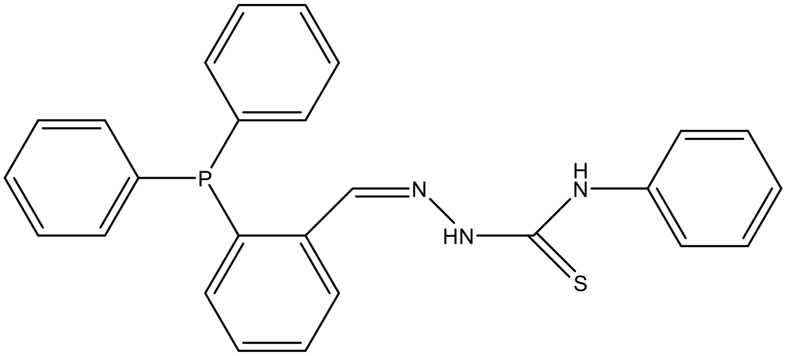
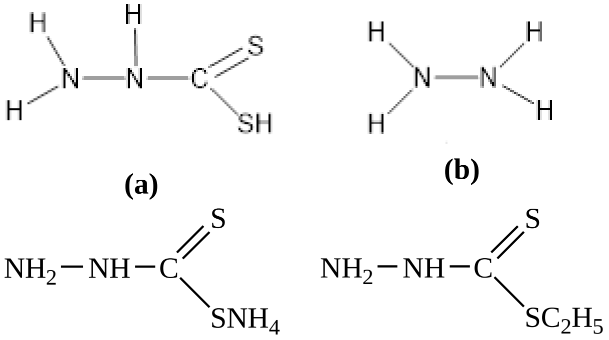


**Figure 5** Ligand HLPPh

***Dithiocarbazate Schiff Bases***

Dithiocarbazates $NH_2NHCS_2$-and their subbed subordinates have been orchestrated and explored in late decades [15]. These mixtures have gotten a lot of consideration and permit additional investigation since (I) they give an intriguing arrangement of ligands whose functionalities can be enormously changed by presenting distinctive natural substituents, in this manner causing a variety in a definitive benefactor property, (ii) the cooperation of these givers with metal particles give buildings of various calculations and properties, and (iii) these edifices are conceivably organically dynamic. Dithiocarbazic acid (**Figure 6a**) is monodithiocarboxy derivative of hydrazine (**Figure 6b**). Free dithiocarbazic acid, $H_2NNHCSSH$, has been isolated, although its ammonium (**Figure 6c**) and hydrazinium (**Figure 6d**) salts have long been known.

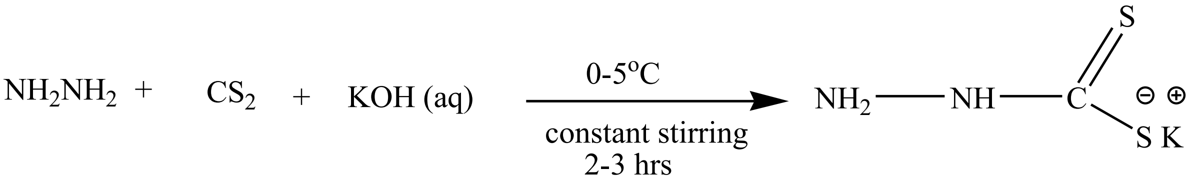


(a) (b)

(c) (d)

**Figure 6** Dithiocarbazate Schiff Bases.

Anthoni [16] made a positive endeavor to disconnect free corrosive and really met with progress. The free corrosive was gotten as white mass when potassium salt of the corrosive was set up by responding carbon disulphide with a combination of $NH_2$-$NH_2$.$H_2O$ and potassium hydroxide in dioxane medium, and treated with hydrochloric acid at 0°C. The free corrosive is similarly decidedly ready from hydrazinium dithiocarbazate by expansion of HCl gave that the response blend was placed in an ice-shower. Free dithiocarbazoic corrosive deteriorates gradually which exhibits that it is less steady than N-subbed dithiocarbazic corrosive.



**Scheme 2** Synthesis of free dithiocarbazoic acid

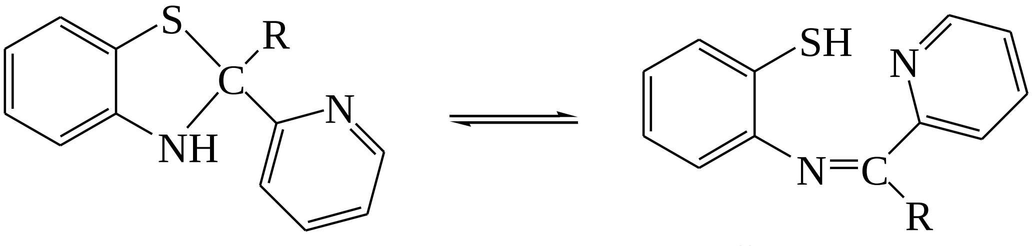
Schiff bases got from S-alkyl/aryl esters of dithiocarbazoic corrosive have been the subjects of impressive investigation. The presence of hard N-and delicate S-contributor particles in the spines of these ligands empower them to respond promptly with both progress and main group metal particles yielding stable metal buildings some have been displayed to show fascinating physico-substance functionalities and critical organic movement. Schiff bases got from S-alkyl/aryl-esters of dithiocarbazoic corrosive frequently go about as flexible chelating specialists and display promising bioactivities.

Schiff base ligands got from S-alkyl esters of dithiocarbazoic corrosive have been found to display checked cytotoxicity against leukemia [17]. In the wake of examining cytotoxic movement of an enormous number of metals chelates of Schiff bases got from S-alkyl esters of dithiocarbazic corrosive, Livingstone and Das proposed that Pd(II) edifices of these ligands are bound to show preferred cytotoxicity over different chelates in light of their high thermodynamic soundness and active lability Schiff base of S-methyldithiocarbazate has been found to show checked action in the P388 Lymphocytic Leukemia test framework. The connected pyridine-2-aldehyde Schiff base of S-benzyldithiocarbazate has been accounted for to frame 1:1 edifices of progress metals, while the 2-acetylpyridine Schiff base of S-methyl dithiocarbazate was found to shape both 1:1 and 1:2 buildings. Some progress metal edifices of the pyridine-2-aldehyde Schiff base of S-methyl dithiocarbazate have additionally been blended. In spite of the fact that there have been various examinations on the arrangement and otherworldly portrayal of edifices, similarly scarcely any gem constructions of these buildings have been accounted for.

Tarafder et al. [18] reported the synthesis, characterization and biological activity of some transition metal (Fe and Co) and non-transition metal (Cd, Pb and Sn) complexes of isomeric N-/Sulphur donor ligands formed between SBDTC with 5-methyl-2-furaldehyde (NS), and 2-furaldehyde (NS).

### *Benzothiazolines*

Benzothiazoles and benzothiazolines have been drawing a lot of consideration of their immense probability as adaptable planning specialists, assortment of natural exercises and various applications in various fields of science. The gathering N-C-S of benzothiazolines and benzothiazole hydrazones is of significant chemotherapeutic interest and is liable for pharmacological movement. The physiological action of these mixtures credited to their capacity to chelate metal particles. The benzothiazolines in presence of metal particles go through different primary changes. Benzothiazolines are not themselves a Schiff bases, but rather are known to frame the relating old style Schiff base edifices (**Figure 7**).



Thiazoline Form Schiff base Form

**Figure 7** Benzothiazolines

Subhi et al. [19] combined some Pd(II) and Pt(II) edifices by the response of benz-1,3-oxazoline-2-thione or benz-1,3-thiazoline-2-thione. Ringer et al. [20] blended cadmium (II) and mercury (II) edifices with 1-methylimidazoline-2(3H)-thione, 1,3-thiazolidine-2-thione and 1,3-benzothiazoline-2-thione (**Figure 8**).

In any case, in arrangement, the benzothiazolidine may exist in harmony with its tautomeric Schiff base which is balanced out by complex development and can't be detached liberated from its related metal particle. Juan R. Anacona [21] revealed the disengagement and portrayal of M(II) buildings (**Figure 9**) containing the Schiff base ligand 2,9-bis[2-(2-mercaptophenyl)-2-azaethene]-1,10 phenanthroline.

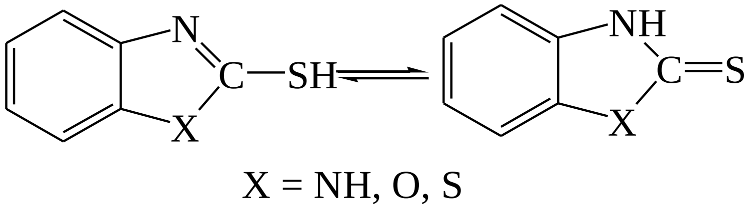


**Figure 8**

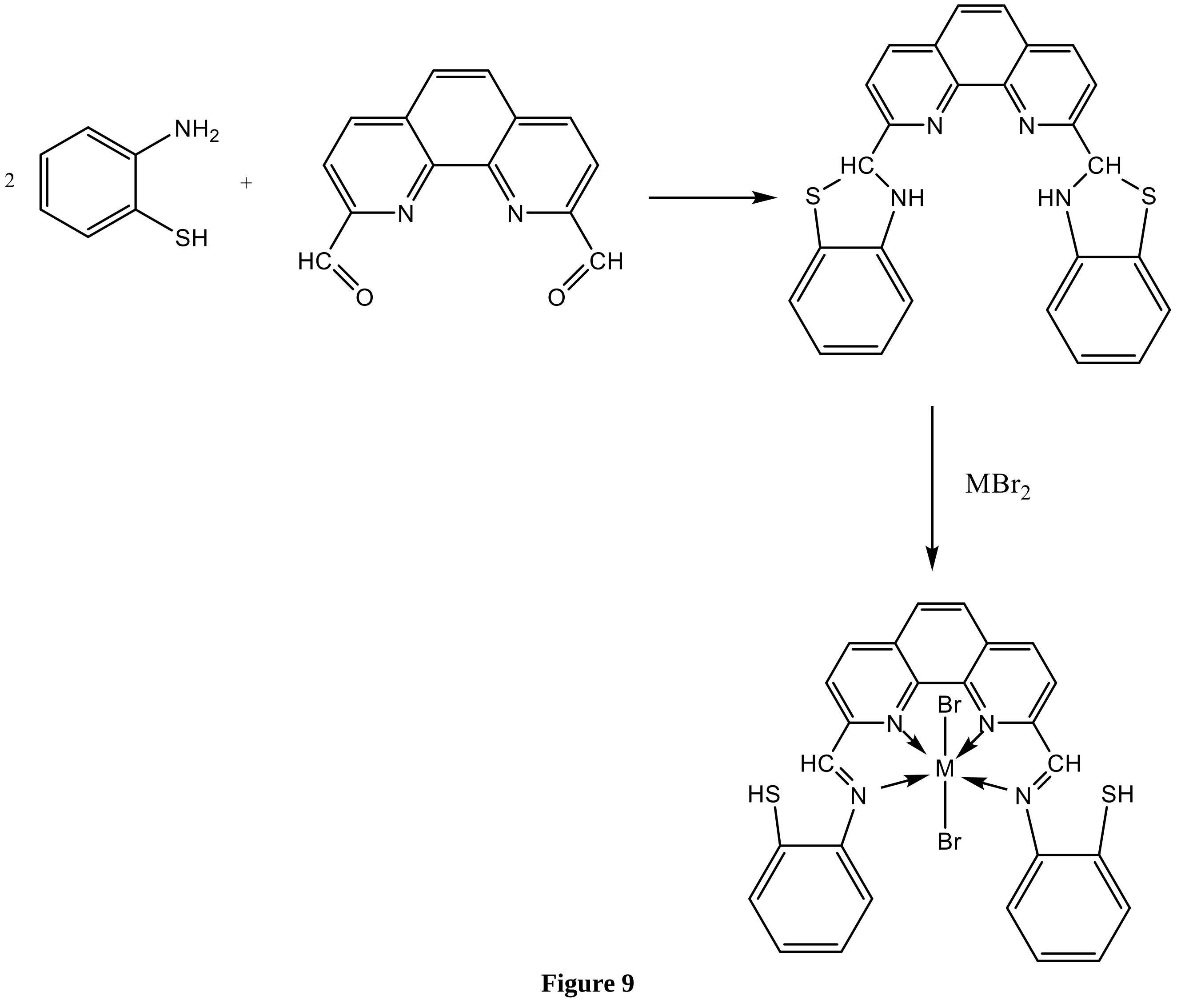
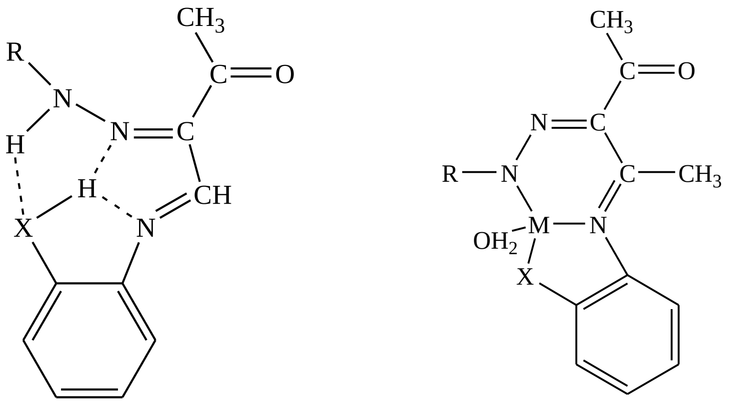


**Figure 9**

Krishnankutty et al. [22] integrated and portrayed some nickel (II), copper (II) and zinc(II) metal edifices of some Schiff bases got from 3-(phenylazo)- and 3-(2-thiazolylazo)- 2,4-pentanedione with 2-aminophenol and 2-aminothiophenol (**Figure 10a-d**).

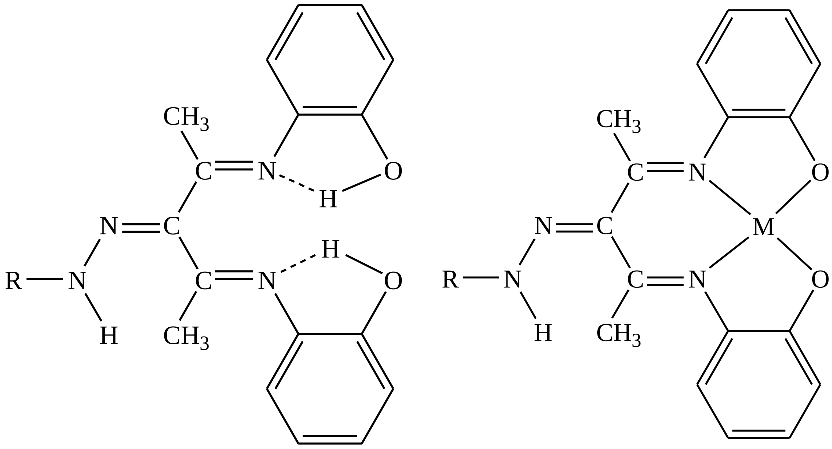
Laxmi et al. [23] synthesized and characterized complexes of 2-acetonyl-2-methylbenzothiazoline (AMBT) and 2-acetyl-3-methyl-4H-1,4-benzothiazine(AM4HBT) and studied their catalytic oxidative ring expansion and structural changes (**Figure 11**).



**(a)** **(b)**

| Compound | R | X |
|---|---|---|
| $H_2$pap | Phenyl | O |
| $H_2$pat | Phenyl | S |
| $H_2$tat | 2-Thiazolyl | S |

M = Ni(II), Cu(II), Zn(II)



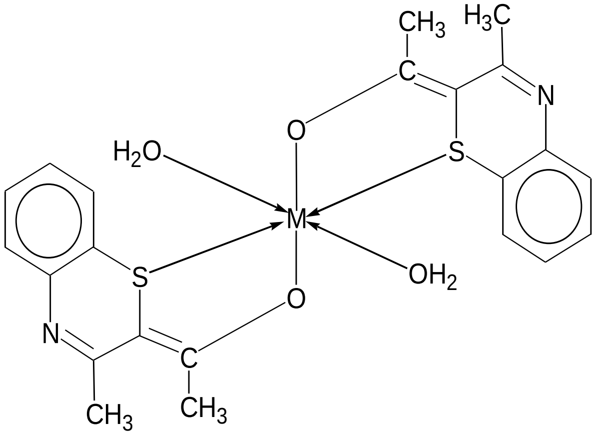
R = 2-Thiazolyl

**(c)**

M = Ni(II), Cu(II), Zn(II)

**(d)**

**Figure 10**



$M^{II}$ = Fe, Co, Ni and Cu

**Figure 11**

### *Acetylferrocenyl Hydrazone*

The coordination science including ferrocene has drawn in incredible interest since it has been found by Kealy and Pauson 50 years prior. The huge number of uses of ferrocene subsidiaries in fields going from non-straight optical materials, electrochemical sensors, fluid precious stones, catalysis and nanoparticles, has added to a high interest in their science. Likewise, the presentation of gatherings with organizing capacities further permits the ferrocenyl moiety to turn into an organometallic ligand, which can tie with other metal habitats to improve their functionalities. Some antitumor action has been distinguished in the ferrocenium particle, and albeit the outcomes were not extraordinary, they were adequately promising to be reached out to extraordinarily planned frameworks. Actually, when ferrocene was presented in specific atoms, their cytotoxic action was upgraded. The flexibility of the ferrocenyl unit, considering generally simple functionalization of a couple of rings, just as the redox capacity of the Fe community, clarifies this achievement, making conceivable the tuning of similar essential unit to various difficulties. The science of ferrocenyl amides containing aminoacids and peptides has been created to incorporate the acquaintance of gatherings capable with tie to organic focuses in endeavors to improve natural applications [24]. The union of ferrocene marked aminoacids has been completed and the ligand ability of new ferrocenyl families toward a few metal parts dissected. Numerous reports have shown that substitution of a fragrant gathering by ferrocenyl family in penicillines and cephalosporins enhances their restorative functionalities. New species and their properties have been concentrated exhaustively, in particular as sensors.

It is notable that ferrocene edifices go through reversible redox responses. Alongside electrochemical functionalities read for their metal edifices, ferrocenyl compounds have been investigated to decide the likely implementations in catalysis, electrical, attractive and brilliant materials.

Barba et al. [25] announced the electrochemical conduct of a progression of eight monoferrocenyl and diferrocenyl-boronates got from tridentate ligands has been examined. Regardless of whether generally mononuclear and all the dinuclear edifices analyzed displayed to go through sluggish deterioration in nonaqueous arrangement (delivering free ferrocenyl boronic corrosive), their redox movement has been researched. It has been demonstrated that the oxidation of the two ferrocenyl subunits in the dimeric species continues all the while, showing that no shared electronic connection exists between them. Furthermore, the strong state sub-atomic designs of two diferrocenyl buildings were concentrated by X-beam diffraction (**Figure 12**). The examination affirms the arrangement of a heterobicycle with the presence of two diverse B iotas, one in a $T_d$ calculation and the other one in a three-sided math.

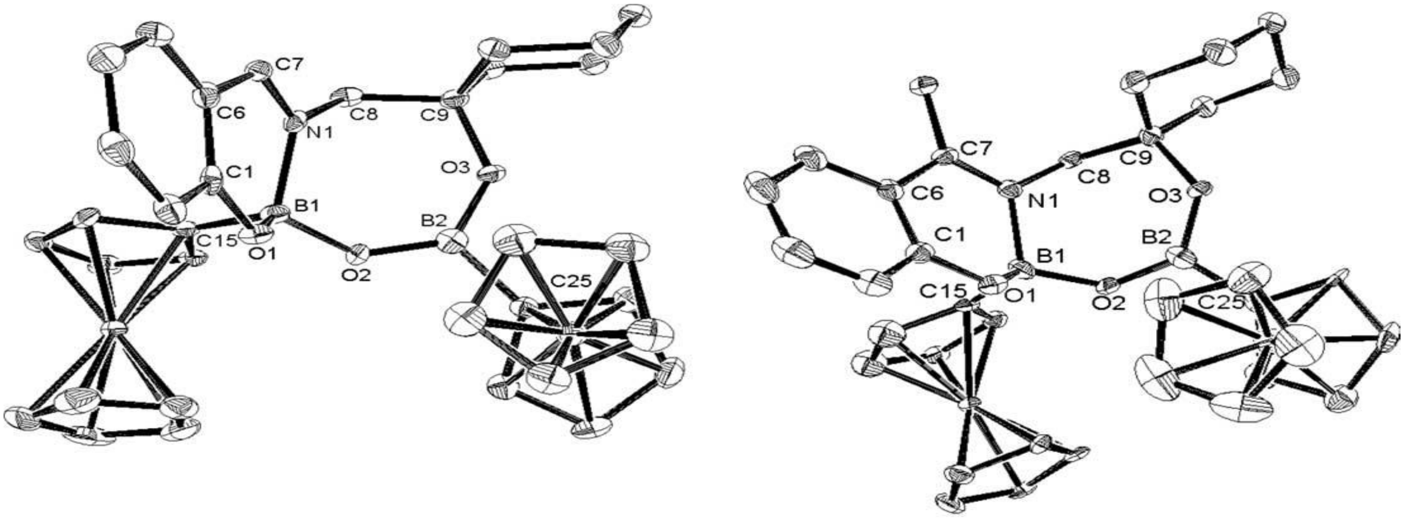


**Figure 12** Perspective view of molecular structures for diferrocenyl complex compounds

Ilkhechi et al. [26] have conveyed a joint experimental and theoretical study of cation-π interactions: Multiple-Decker Sandwich Complexes of Ferrocene with Alkali Metal Ions ($Li^+$, $Na^+$, $K^+$, $Rb^+$, $Cs^+$).

## Conclusion

Schiff bases are considered as advantaged ligands since they are effectively set up by a basic one pot buildup of an aldehyde and essential amines. Progress metal subsidiaries of these ligands had an assortment of utilizations including clinical and pharmacological in light of their capacity to shape edifices. One of the significant difficulties confronting society today is that a considerable lot of the pathogenic organic entities have become impervious to normal medications. A superior comprehension of the primary highlights of the Schiff bases and their buildings can improve the natural properties prompting the plan of novel metallodrugs that are not so much harmful but rather more viable for therapeutic applications.

## Acknowledgement

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## References

[1] A.D. Garnovskii, I.S. Vasilchenko, D.A. Garnovskii, B.I. Kharisov. 2009. Molecular design of mononuclear complexes of acyclic Schiff-base ligands. J. Coord. Chem., 62, 151-204.
[2] J. Hine, C.Y. Yeh. 1967. Equilibrium in formation and conformational isomerization of imines derived from isobutyraldehyde and saturated aliphatic primary amines, J. Am. Chem. Soc., 89, 2669.
[3] C. Munir, S. M. Yosuf, N. Ahmad. 1985. Synthesis, characterization and pharmacological properties of a cobalt (ii) complex of antibiotic ampicillin. J. Chem. Soc. Pak., 7(3), 301.
[4] S. Akhter, H. Ulzaman, S. Mir, A.M. Dar, S. Shrivastava. 2017. Synthesis of Schiff base metal complexes: A concise review. Eur. Chem. Bull., 6(10), 475.
[5] M. Biyala, K. Sharma, M. Swami, N. Fahmi. 2008. Spectral and biocidal studies of palladium(II) and platinum(II) complexes with monobasic bidentate Schiff bases. Trans. Met. Chem., 33(3), 377-381.
[6] A.P. Mishra, M. Soni. 2008. Synthesis, Structural, and Biological Studies of Some Schiff Bases and Their Metal Complexes. Met Based Drugs., 875410.
[7] S. Ren, R. Wang, K. Komatsu, P. Bonaz-Krause, Y. Zyrianov, C. E. McKenna, C. Csipke, Z. A. Tokes, E. J. Lien. 2002. Synthesis, Biological Evaluation, and Quantitative Structure−Activity Relationship Analysis of New Schiff Bases of Hydroxysemicarbazide as Potential Antitumor Agents. J. Med. Chem., 45(2), 410-419.
[8] N. Raman, V. Muthuraj, S. Ravichandan, A. Kulandaisamy. 2003. Synthesis, characterization and electrochemical behaviour of Cu(II), Co(II), Ni(II) and Zn(II) complexes derived from acetylacetone and p-anisidine and their antimicrobial activity. J. Chem. Sci., 115(3), 161.
[9] Z. Yu, M. He, P. Sun, W. Zhang, L. Chang. 2009. Crystal structure of trinuclear nickel(II) complex with Schiff base ligand N, N'-bis(salicylidene)-1, 3-diiminopropane. J Chem Crystallogr., 39, 885–9.
[10] J. Han, Y. Xing, C. Wang, P. Hou, F. Bai, X. Zeng, X. Zhang, M. Ge. 2009. Two complexes (Cu, Zn) with 1,10-phenanthroline and a tridentate amino-Schiff-base: crystal structures, spectra, thermogravimetric analyses and superoxide dismutase activity. J. Coord. Chem., 62(5), 745.
[11] I.C. Mendes, L.M. Botion, A.V.M. Ferreira, E.F. Castellano, H. Beraldo. 2009. Vanadium complexes with 2-pyridineformamide thiosemicarbazones: In vitro studies of insulin-like activity. Inorganica Chimica Acta., 362(2), 414–20.
[12] K.J. Duffy, A.N. Shaw, E. Delorme, S.B. Dillon, C. Erickson-Miller, L. Giampa, Y. Huang, R.M. Keenan, P. Lamb, N. Liu, S.G. Miller, A.T. Price, J. Rosen, H. Smith, K.J. Wiggall, L. Zhang, J.I. Luengo. 2002. Identification of a pharmacophore for thrombopoietic activity of small, non-peptidyl molecules. 1. Discovery and optimization of salicylaldehyde thiosemicarbazone thrombopoietin mimics. J. Med. Chem., 45(17), 3573-5.
[13] D.C. Quenelle, K. A. Keith, E. R. Kern. 2006. In vitro and in vivo evaluation of isatin-beta-thiosemicarbazone and marboran against vaccinia and cowpox virus infections. Antivir. Res. 71, 24-30.
[14] A. Castineiras, R. Pedrido. 2008. Factors Involved in the Nuclearity of Silver Thiosemicarbazone Clusters: Cocrystallization of Two Different Sized Tetranuclear Silver(I) Clusters Derived from a Phosphinothiosemicarbazone Ligand. Inorganic Chemistry, 47(13), 5534-5536.
[15] M. Tofazzal, H. Tarafder, M. A. Ali, N. Saravanan, W. Y. Weng, S. Kumar, N. Umar Tsafe, K. A. Crouse. 2000. Coordination Chemistry and Biological Activity of Two Tridentate ONS and NNS Schiff Bases Derived from S-Benzyldithiocarbazate. Transition Metal Chemistry, 25(3), 295-298.
[16] U. Anthoni, B. M. Dahl, P. H. Nielsen. 1969. Derivatives of Hydrazine. III. Dithio- and Diselenocarbazic Acid. Acta Chem. Scand, 23, 1061.
[17] M. Das, S.E. Livingstone. 1978. Metal chelates as anticancer agents II. Cytotoxic action of palladium and platinum complexes of 6-mercaptopurine and thioguanine. Br. J. Cancer, 38, 325-329.
[18] M.T.H. Tarafder, T.J. Khoo, K.A. Crouse, A.M. Ali, B.M. Yamin, H.K. Fun. 2002. Coordination chemistry and bioactivity of $Ni^{2+}$, $Cu^{2+}$, $Cd^{2+}$ and $Zn^{2+}$ complexes containing bidentate Schiff bases derived from S-benzyldithiocarbazate and the X-ray crystal structure of bis[S-benzyl-β-N-(5-methyl-2-furylmethylene)dithiocarbazato]cadmium(II). Polyhedron, 21, 2547-2554.
[19] S. A. Al-Jibori, A. S. S. Al-Zaubai, M. Y. Mohammed, T.A.K. Al-Allaf. 2007. Mixed ligand palladium(II) and platinum(II) complexes of tertiary diphosphines and benz-1,3-imidazoline-2-thione, benz-1,3-oxazoline-2-

thione or benz-1,3-thiazoline-2-thione. Transition Met. Chem., 32(3), 281.

[20] N.A. Bell, W. Clegg, S.J. Coles, C.P. Constable, R.W. Harrington, M.B. Hursthouse, M.E. Light, E.S. Raper, C. Sammon, M.R. Walker. 2004. Complexes of heterocyclic thiones and group 12 metals: Part VI. Preparation and characterisation of complexes of cadmium(II) halides with 1-methylimidazoline-2(3H)-thione, 1,3-thiazolidine-2-thione and 1,3-benzothiazoline-2-thione. Crystal structures of polymeric (1,3-thiazolidine-2-thione)cadmium(II) chloride, bis(1,3-thiazolidine-2- thione)cadmium(II) iodide and monomeric bis(1-methylimidazoline-2(3H)-thione)cadmium(II) bromide. Inorg. Chim. Acta, 357(7), 2091-2099.

[21] J. Anacona, V.E. Marquez. 2008. Synthesis of transition metal complexes containing a Schiff base ligand derived from 1,10-phenanthroline-2,9-dicarboxaldehyde and 2-aminobenzenethiol. Transition Met. Chem., 33(5), 579-583.

[22] K. Krishnankutty, P. Sayudevi, M.B. Ummathur. 2007. Metal complexes of Schiff's bases derived from 3-arylazo-2,4-pentanediones with 2-AMinophenol and 2-Aminothiophenol. J. Serb. Chem. Soc., 72(11), 1075.

[23] K. Laxmi, G. Bhargavi, G. Kumari, S. Devi. 2004. Catalytic oxidative ring expansion and structural changes in 2-acetonyl-2-methyl benzothiazoline involving some metal ions. J Indian chem. Soc., 81(3), 236-8.

[24] D.R.V. Staveren, N. Metzler-Nolte. 2004. Bioorganometallic chemistry of ferrocene. Chem. Rev., 104(12), 5931-85.

[25] V. Barba, N. Farfán, S. Losi, P. Zanello. 2006. Ferrocenylboronates: Crystal Structures and Electrochemical Properties. Inorganica Chim. Acta, 359 (4), 1269–1274.

[26] A. H. Ilkhechi, J. M. Mercero, I. Silanes, M. Bolte, M. Scheibitz, H.W. Lerner, J. M. Ugalde, M. Wagner Ilkhechi. 2005. A Joint Experimental and Theoretical Study of Cation−π Interactions: Multiple-Decker Sandwich Complexes of Ferrocene with Alkali Metal Ions ($Li^+$, $Na^+$, $K^+$, $Rb^+$, $Cs^+$). J. Am. Chem. Soc., 127(30), 10656.

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