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Analytical Study Interaction Studies Of Deoxyribonucleic Acid With Metal Complexes And Their Mechanism

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Deoxyribonucleic acid (DNA) is a biopolymer consisting of each nucleotide and, through Watson Crick hydrogen bonds, is combined with two other nucleotide monomers in polymer chain. Through phosphodiester connections, those nucleotides inside strands are connected to the 3' carbon of a sugar of a nuclear fibre by the hydroxyl group in the phosphate group, which forms an ester bond with the phosphate of another 5' end of the nuclear sugar carbon, and eliminates a molecule of water. The following three fundamental building components, such as an aromatic planar derivative of a pyrimidine (thymine & cytosine)/purine base (adenine & guanine), sugar deoxyribase, and a group of phosphates, constitute a nucleotide monomer. B-DNA is the most frequent type of conformational helix of the dsDNA base pair (Shamsi & Kraatz 2012) (Table 1.5).

Table 1.5 Some features of DNA forms: A, B and Z forms

Geometry attribute	A-form	B-form	Z-form
Helix sense right	Right-Handed	Right-Handed	Left-Handed
Repeating Unit	1bp	1bp	2bp
Rotation / bp	32.7°	34.3°	60°/2
Mean bp / turn	11	10.5	12
Pitch /	28.2 A°	33.2 A°	45.6 A°

turn of helix	(2.82 nm)	(3.32 nm)	(4.56 nm)
Nucleotide phosphate to phosphate distance	5.9 A°	7.0 A°	C: 5.7 A° G: 6.1 A°
Diameter	23 A° (2.3 nm)	20 A° (2.0 nm)	18 A° (1.8 nm)

DNA and RNA play a key function in live cell systems, and for many natural, synthesized organic compounds, they represent the most essential cellular target. In particular, anticancer, antiviral and antibacterial medicines function as carriers of hereditary information encoded as genes and used by the transcripts and replication to biosynthesize enzymes and proteins (Ma et al. 2012; Singh et al. 1992 and Sparks & Scholz 2009). DNA is often copied and transcribed by DNA and RNA polymerases in the nucleus carrying genetic information. While certain other biological targets in tumour cells, such RNA, enzyme or protein, are widely considered to be the main objective for many anti-cancer medicines (Reddy & Shilpa 2011). The study of the interaction of DNA is thus of primary significance for the creation and development of drugs. In addition, DNA cleavage may be seen as an enzyme reaction involving several biological processes as well as biotechnological genetic material manipulation. It has a broad range of applications in bio-organic, molecular and medical design applications etc (Reddy & Shilpa 2011). Since nucleic acid and biomolecular interactions are complex, knowledge on comparable reactions with tiny molecules needs to be collected. It is observed that bioactive ligands with a low molecular weight also identify and interact with DNA. These ligands and their metal complexes have the extraordinary biological power to bind cell-based DNA and cause single or two stranded breaks with high efficiency (Reddy & Shilpa 2011). The interactions between transitional metal complexes and DNA have been attractive because of their significance in cancer and molecular biology (Yang et al. 2008). However, three major activities in prokaryotic and eukaryotic cells are involved. Eukaryotic cells have nuclei (e.g. human animals, plants, fungus and insects) and are without nuclei (e.g. bacteria). A large size (diameter range: 10-100 μm) of eukaryotic cells with much more DNA/proteins than prokaryotic cells (diameter range: 0.1-5.0 μm). Linear DNA in eukaryotic cells and smaller circular DNA in prokaryotic cells. The complete ribosome / mRNA complex attaches to the outer membrane of the endoplasmic reticule in eukaryotic cells (ER). They manufacture polypeptides and the newly produced polypeptide

for further liposome vesicle transport and secretion outside the cell may be stored within the ER.

(i) Transcription

Transcription is the initial stage in the gene expression in which a certain sequence of DNA with the aid of the RNA polymerase enzyme has been transcribed into the RNA (ssmRNA/coding or sensory strand). In biology, transcription is also a process of replicating the gene DNA sequence in the comparable RNA alphabet. However, a gene is transcribed in three phases: initiation, elongation and termination. In the initiation phase, RNA polymerase enzymes are linked to a particular DNA sequence, termed a promoter, and then the DNA strands are separated and the single-stranded transcription template generated. Promoter area is a specially identified active location of dsDNA to bind or support RNA polymerase enzyme. While dsDNA opens at the promoter area, a transcription process may begin using the RNA polymerase enzyme. During transcription, the RNA enzyme synthesises the additional RNA strand 5'-AUGAUCUCGUAA-3' direction from the 3'-ACCATCAGTC-5' direction single-strand DNA template. Genetic data are recuperated by Ribonucleic acid (RNA) from DNA and used for the synthesis of proteins in the body, which are also influencing all biological processes and play a key part in the production of hormones, enzymes, structural proteins (Figure 1.5).

(ii) Replication

The DNA is responsible for its own regeneration (dna self replicates) and is a biological process in which two comparable DNA copies are generated from the base pair of the DNA. This process is founded on biological legacy in all living things. These strands are split by a single strand DNA helicase enzyme during replication. Each strand of the original DNA molecule serves as a model for its counterpart creation, known as semi-conservative replication. The procedure takes place in three stages (a). Initiation: beach septic tissues in presence of helicase that catalyses hydrolysis of Adenosine Triphosphate (ATP) and utilises this energy to disconnect strands during réplication by breaking the hydrogen link between base pairs. In the meanwhile, DNA topoisomerase enzyme cleaves the phosphodiester connection between nucleic acids on a regular basis (Schoeffler & Berger 2008). This process is reversible and the phosphodiester bond may thus be reformed when the enzyme is removed from the DNA strand. There are also two kinds of topoisomerases, which may be distinguished on mechanical and structural grounds. The topoisomerase enzymes of type I create a one-beach break at a time, while the topoisomerase enzymes of type II (DNA Gyrase)

produce a coordinated dual beach break. The single stranded DNA fragments are bound with protein and the short RNA primers nucleotide sequence (b). Elongation: DNA polymerase III enzymes connect DNA fragments (okazaki fragments identified by Reiji Okazaki) in sequence order to template strands as well as assist in revision and remediation of new strands. (c). Termination: the DNA ligase controls the arrangement for the DNA fragment by filling the gaps and closes the nick in double stranded DNA. In the meanwhile, DNA polymerase I helps remove the RNA primers and balance the gaps (Figure 1.5).

(iii) Genetic translation

The translation of genetic information takes place in the live cell system from RNA to protein. During transcription, DNA creates messenger RNA (mRNA) in the nucleus of the cell. The mRNA serves as a template to translate the protein production. The transcribed gene, on the other hand, can encode non-coding RNAs such as ribosomal RNA (rRNA), transmission of RNA (tRNA)/enzyme RNA molecules known as ribocids and of small RNAs such as microRNA, small interfering / silenting (siRNA), piwi-interacting RNA (piRNA), small nucleolary RNA (SnoRNA), small nuclear RNA (snARN), extracellular RNA (exRNA), etc. The ribosome is used to manufacture the amino acid protein in all living cells as a sophisticated molecular mechanism and the RNA helps synthesise and control the proteins process. Ribosomes and tRNA are performed together in the cytoplasm of eukaryotic cells to convert the mRNA into a protein. This process is referred to as genetic translation. While the many individual DNA sequences were transcribed with the support of several RNA polymerase enzymes into RNA molecules, the vast numbers of proteins may be produced in live cells. In addition, the ribosomes assemble around the target mRNA and the first tRNA (first mRNA codon) is connected at the start of the amino acid chain. When a stop codon is achieved, the polypeptide is released by the ribosome. Numerous medications such as anisomycin, clindamycin, streptomycin, erythromycin, puramycin, tetracycline, cycloheximide, and chlororamphenicol suppress prokaryotic cell translation. However, owing to the prokaryotic ribosomes, the adverse effects may mostly decrease from the eukaryotic ribosome in structure (Figure 1.5)

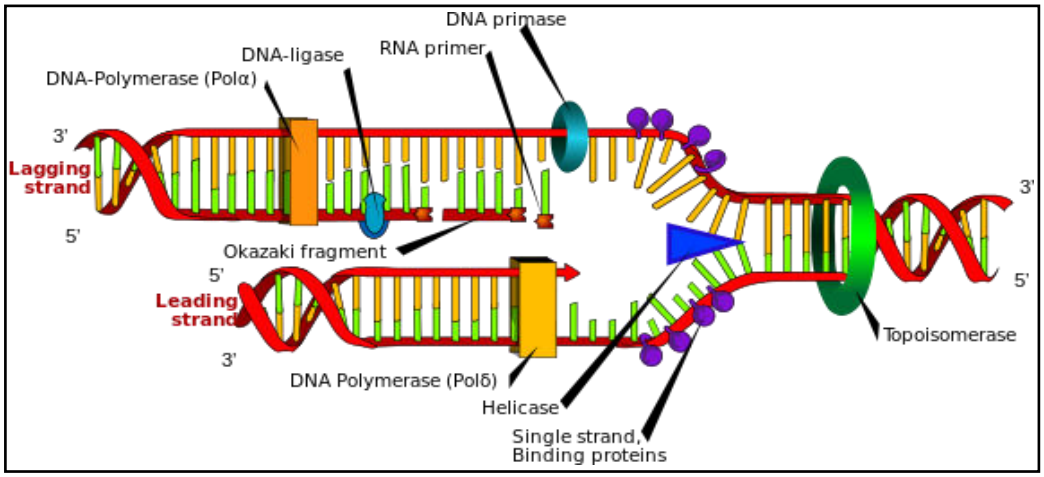

FIGURE DNA TRANSCRIPTION, REPLICATION AND GENETIC TRANSLATION PROCESS

In addition, single/divalent metal cations play significant structural and physiological roles in all living cells (Izatt et al. 1971). They also help to stabilise the DNA structure via phosphodiester coordination (Neidle 2008). The multivalent cation interaction between two phosphate strands of B-DNA was established by Rouzina and Bloomfield in 1998. As a consequence, the phosphates on both strands are interacting strongly with the groove. This induces groove closure and the bending of DNA into the cationic molecule (Figure 1.6) (Bloomfield & Rouzina 1998).

Mechanism: How a medication molecule may interact with the DNA are various: I Transcription factors control: the medication molecule does not interact directly with the DNA. They initially attach to the protein, which then interacts with the DNA base pair when the functions change. (ii). Forming DNA-RNA hybrids. Binding to an RNA molecule that binds in turn to single stranded DNA hybrids that generate DNA-RNA hybrids that impede transcripts. (iii). Direct molecular binding: The tiny medication molecules attach directly to a double helix DNA. In general there are two types of interactions between DNA and metal ions, (a) ligand/complex-mediated relationships via the H-bound, Ţ–α interaction between a complex metal and DNA base pairs by intercalation or shape-selective groove bonding and (b) direct metal ion bonding with DNA that involve the interaction between the filled orbital of the nucleo-base ligand with the appropriate emp interaction (Barton & Lolis 1985).

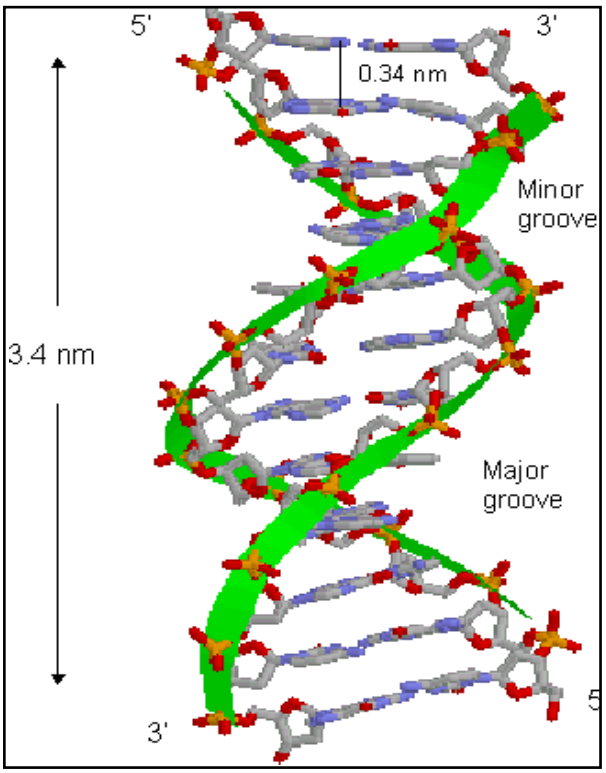

Figure 1.6 DNA structure and its grooves

1.9.1 Radical Scavenging Abilities Towards DPPH (DPPH•)

The Brand-Williams (Brand-Williams et al. 1995) technique created and uses the stable free radical DPPH, which has a deep purple colour and can be detected spectrophotometrically. In the presence of molecules able to transport an electron or to donate hydrogen, the DPPH becomes bright yellow in an aqueous solution. Due to the fast, easy and cheap technique, the radical capability for scavenging in medical and food technology is extensively measured (Arnab et al. 2010). However, they may also affect the absorption at the same wavelength in certain limits because of steric hurdles during the interaction of small molecules with biomolecules and carotenoids (Karamac et al. 2011).

1.9.2 Radical Scavenging Abilities Towards Hydroxyl (• OH)

Hydrogen peroxide has high oxidising characteristics. It consists of numerous oxidising enzymes such as SOD. The Ruch technique is used to evaluate the free radical scavenging capability of H2O2. OH• Scavenging is the most important antioxidant activity owing to extremely high reactivity and severe oxidation characteristics. While hydroxyl radical

intensities in cells rise, they may contribute to toxicity in live cells (Mandade et al. 2011). The OH• radicals produced in the presence of reduced transition metals/H2, and the reduced form of dioxygen, cause cell damage in vivo according to the Fenton reaction (Duan et al. 2007) OH• is most essential antioxidant activity owing to its extremely high reactivity and oxidation characteristics; OH• interacts with a variety of biomolecules, including amino acids, lipids, sugars and nucleotides. It ends up damaging the live cells. Therefore, the OH• production prevention method plays an important function in the preservation of living systems (Wang et al. 2008).

1.9.3 Radical Scavenging Abilities Towards Superoxide (O2•−)

Superoxide dismutase (SOD) is an essential antioxidant that protects all living cells and acts as a catalytic for discharge into ordinary molecular oxygen or H2O2 of superoxides radically anion. During the respiratory chain process, superoxide anion radical is generated as a by-product of oxygen metabolism. Excess O2•− should be rapidly eliminated from the biological system because of toxicity. The SOD helps to avoid excess O2•− radicals to protect live cells.

$$O_2^{\bullet -} + O_2^{\bullet -} + 2H^{+} \xrightarrow[SOD]{} H_2O_2 + {}^1O_2$$

$$O_2^{\bullet -} + H_2O_2 \xrightarrow[\text{Reducing agent}]{} HO^{\bullet} + HO^{\bullet} + {}^1O_2$$

The radical reaction of OH• to O2•− also produces the excited molecular oxygen. The superoxide is a comparatively low oxidant compared to nitrogen oxide and hydroxyl oxidative species (Miguel et al. 2014). Superoxides are also known to promote lipid peroxidation as a consequence of the production of H2O2, generating hydroxyl radical precursors (Sun et al. 2010). Even though superoxide anion radicals themselves are not reactive to biomolecules and are more potent in the formation of the SAOO and ONOO−. During mitochondrial respiration, the radical superoxide anion is generated by various enzymes such as nicotinamide Adenine Dinucleotide Phosphate Oxidase (NADPH), monooxygenases, xanthine oxidases (XO) and cyclooxygenases in significant amounts for destroying pathogenes. The dominating superoxide anion radicals cause the biological system to suffer from many damaging alterations. Hydrogen is donated to superoxide radicals by antioxidants, resulting in detoxification, suppression of lipid oxidation propagating phases and peroxidant reactions.

1.9.4 Radical Scavenging Abilities Towards Nitric Oxide (NO•)

The radical nitric oxide is an important chemical mediator that is caused by endothelial cells, macrophages and neurons and involved in the control of many physiological processes. NOTA is manufactured via three nitric oxide synthase isoforms, endothelial NOS, neural NOS and inducible NOS (iNOS). Nitric oxide is produced by enzymes in the vascular endothelial cells, neural cells and phagocytes of amino acid L-arginine. NO THE supports diseases such as cancer, Alzheimer's disease, AIDS, arthritis and so forth. While NOTE intensity grows, division of the DNA, cell damage and neural cell death in the human body may occur (Dawson et al. 1992). NO ret is unstable in aerobic circumstances, producing intermediate reactions with oxygen NO2, N2O4, and N3O4. The stable products nitrite and nitrate (Marcocci et coll. 1994) and peroxynitrite likewise generated by interacting with superoxide were synthesised in this process. These compounds are genotoxic and the deamination of guanine, cytosine and adenine is mainly mediated by N2O3. Chronic exposure to radical nitric oxide is associated with many carcinomas and inflammatory diseases, including diabetes of young people, multiple sclerosis, arthritis and ulcerative colitis. The toxicity of NO cal rises significantly when it combines with radical superoxide and forms a highly reactive peroxynitrite anion (ONO−) (Boora et al. 2014).

REFERENCES

1. Sakthikumar K, “AN OVERVIEW OF HISTORICAL MILESTONE AND BIOLOGICAL IMPLICATIONS OF POTENTIAL DRUGS BEARING SCHIFF BASE LIGANDS AND THEIR METAL COMPLEXES” Xl,378p.,http://hdl.handle.net/10603/299007
2. N. S. Al-barki et al, “Synthesis and Physiochemical Studies of Some Mixed Schiff Bases Complexes” , Academic Journal of Chemistry ISSN(e): 2519-7045 Vol. 1, No. 3, pp: 66-75
3. Mahasin Alias, Huda Kassum, Carolin Shaki, “Synthesis, physical characterization and biological evaluation of Schiff base M(II) complexes”, Journal of the Association of Arab Universities for Basic and Applied Sciences, 1815-3852
4. Malik, S., Ghosh, S., Mitu, L., 2011. Complexes of some 3d-metals with a Schiff base derived from 5-acetamido-1,3,4-thiadiazole-2- sulphonamide and their biological activity. J. Serb. Chem. Soc. 76 (10), 1387–1394
5. Aderoju A. Osowole, “Synthesis, Physicochemical, and Biological Properties of Nickel(II), Copper(II), and Zinc(II) Complexes of an Unsymmetrical Tetradentate Schiff Base and Their Adducts” , Journal of Coordination Chemistry, Pages 829-836
6. Aliyu, H. N., Kurawa, M. A. and Sani, U., “Synthesis and Physicochemical Properties of Copper (II) Complex with a Schiff base Derived from 2 – Hydroxy – 1 – naphthaldehyde and Ethylenediammine”,

Chemsearch Journal 3(2): 39 – 45, December, 2012 Publication of Chemical Society of Nigeria, Kano Chapter Date Received: August, 2012 Date Accepted: October, 2012 ISSN: 2276 – 707X

7. SANJOY SAHA, GOUTAM BASAK and BISWAJIT SINHA, "Physico-chemical characterization and biological studies of newly synthesized metal complexes of an Ionic liquid-supported Schiff base: 1-{2-[(2-hydroxy-5-bromobenzylidene)amino]ethyl}-3- ethylimidazolium tetrafluoroborate", J. Chem. Sci. (2018) 130:9 https://doi.org/10.1007/s12039-017-1409-9
8. AbdurRauf, et al., "Synthesis, physicochemical elucidation, biological screening and molecular docking studies of a Schiff base and its metal(II) complexes", Arabian Journal of Chemistry Volume 13, Issue 1, January 2020, Pages 1130-1141
9. Dinesh Kumar, Amit Kumar, and Jyoti Sharma, "Physico-Chemical Studies on the Coordination Compounds of Thiazolidin-4-One" , Journal of Chemistry Volume 2013, Article ID 870325, 7 pages http://dx.doi.org/10.1155/2013/870325
10. C. Anitha, C. D. Sheela, P. Tharmaraj, and R. Shanmugakala , " Studies on Synthesis and Spectral Characterization of Some Transition Metal Complexes of Azo-Azomethine Derivative of Diaminomaleonitrile", International Journal of Inorganic Chemistry Volume 2013, Article ID 436275, 10 pages http://dx.doi.org/10.1155/2013/436275
11. Ismail Warad, "Synthesis and physicochemical, DFT, thermal and DNA-binding analysis of a new pentadentate N3S2 Schiff base ligand and its [CuN3S2]2+ complexes", The Royal Society of Chemistry 2020, 21806–21821
12. Hanan A. Althobiti and Sami A. Zabin, "New Schiff bases of 2-(quinolin-8-yloxy)acetohydrazide and their Cu(ii), and Zn(ii) metal complexes: their in vitro antimicrobial potentials and in silico physicochemical and pharmacokinetics properties", the journal Open Chemistry https://doi.org/10.1515/chem-2020-0085
13. A. P. Mishra, Neha Sharma, Rajendra K. Jain, "Microwave Synthesis, Spectral, Thermal and Antimicrobial Studies of Some Ni(II) and Cu(II) Schiff Base Complexes", Open Journal of Synthesis Theory and Applications > Vol.2 No.2, April 2013
14. Mohammad Nasir Uddin et al., "Titanium (IV) complexes of some tetra-dentate symmetrical bis-Schiff bases of 1,6-hexanediamine: Synthesis, characterization, and in silico prediction of potential inhibitor against coronavirus (SARS-CoV-2)", Appl Organomet Chem. 2021;35:e6067. wileyonlinelibrary.com/journal/aoc. 1of17https://doi.org/10.1002/aoc.6067
15. Enis Nadia Md Yusof et al., "Synthesis, Characterization and Biological Evaluation of Transition Metal Complexes Derived from N, S Bidentate Ligands",International Journal of Molecular Sciences, 2015 May; 16(5): 11034–11054. doi: 10.3390/ijms160511034
16. S.Arulmurugan, Helen P. Kavitha and B.R. Venkatraman, "BIOLOGICAL ACTIVITIES OF SCHIFF BASE AND ITS COMPLEXES: A REVIEW",RASAYAN J. Chem., Vol.3, No.3 (2010), 385-410 ISSN: 0974-1496
17. Ehsan Ullah Mughal, "Terpyridine-metal complexes: effects of different substituents on their physico-chemical properties and density functional theory studies", ROYAL SOCIETY OPEN SCIENCE,

18. SHUANG HANa, YUAN WANG, "SYNTHESIS, STRUCTURAL CHARACTERIZATION AND CATALYTIC OXIDATION PROPERTY OF SCHIFF BASE COPPER(II) COMPLEXES", Journal of the Chilean Chemical Society versión On-line ISSN 0717-9707, vol.59 no.4 Concepción dic. 2014
19. NETRA PAL SINGH* and ABHAY NANDA SRIVASTAVA, "Physico-chemical and biological studies of Cu(II), Co(II) and Ni(II) complexes of an N4 coordinating ligand derived from the Schiff base of diacetyl with ethylenediamine and benzoic acid", J. Serb. Chem. Soc. 77 (5) 627–637 (2012)
20. Dhokale NT, Karale BK, Nagawade AV. Synthesis and Physico-Chemical Properties of Transition Metal Complexes with 2,4- Dichloro-6-{(hydroxyimino) [1-(4-methylphenyl)-1H-Pyrazol-4-yl] methyl} Phenol. Dhokale NT, Karale BK and Nagawade AV. Int J Chem Sci. 2017;15(2):138.
21. Ajaykumar D Kulkarni, "Schiff's Bases Metal Complexes in Biological Applications", J Anal Pharm Res 5(1): 00127.
22. Sheida Esmaielzadeh, Elham Zarenezhad, "Copper(II) Schiff Base Complexes with Catalyst Property: Experimental, Theoretical, Thermodynamic and Biological Studies", Copper(II) Schiff Base Complexes with Catalyst Property: Experimental, Theoretical, Thermodynamic and Biological Studies, DOI: 10.17344/acsi.2018.4159
23. Shubham Kashyap et al. "Synthesis, biological evaluation and corrosion inhibition studies of transition metal complexes of Schiff base",Chemistry Central Journal volume 12
24. A.A. Maihub, M.M. El-ajaily, "A Review Synthesis, Characterization and Biological Applications of Schiff Base Complexes Containing Acetophenone or Resemblance Compounds ", Chemistry Journal Vol 1 No 2 (2018) ISSN: 2581-7507
25. N. Raman, R. Jeyamurugan, R. Senthilkumar, B. Rajkapoor, S.G. Franzblau, Eur. J. Med. Chem. 45 (11) (2010) 5438.
26. M.H. Habibi, E. Shojaee, M. Ranjbar, H.R. Memarian, A. Kanayama, T. Suzuki, Spectrochim. Acta 105A (2013) 563.
27. W.J. Lian, X.T. Wang, C.Z. Xie, H. Tian, X.Q. Song, H.T. Pan, X. Qiao, J.Y. Xu, Dalton Trans., 45 (2016) 9073.
28. J.A. Smith, F.R. Keene, F. Li, J.G. Collins, Noncovalent DNA binding of metal complexes, in: J. Reedijk, K. Poeppelmeier (Eds.), Comprehensive Inorganic Chemistry II: from Elements to Applications, Elsevier, Oxford, UK, 2013, pp. 709– 750.
29. J. Gao, Y. Guoa, J. Wang, Z. Wang, X. Jin, C. Cheng, Y. Li, K. Li, Spectrochim. Acta. A 78 (2011) 1278.
30. M.T. Rehman, S. Ahmed, A.U. Khan, J. Biomolecular structure & dynamics, (2015) 1.
31. T. Storr, K. H. Thompson, C. Orvig, Design of targeting ligands in medicinal inorganic chemistry, Chem. Soc. Rev., 35 (2006) 534.
32. Y. Shibuya, K. Nabari, M. Kondo et al., "The copper(II) complex with two didentate schiff base ligands.The unique rearrangment that proceeds under alcohol vapor in the solid state to construct non-inclusion structure," Chemistry Letters, vol. 37, no. 1, pp. 78– 79, 2008.
33. B. J. Gangani and P. H. Parsania, "Microwave-irradiated and classical syntheses of symmetric double Schiff bases of 1,1□ -bis(4-aminophenyl)cyclohexane and their physicochemical characterization," Spectroscopy Letters, vol. 40, no. 1, pp. 97–112, 2007.

34. B. S. Kumari, G. Rijulal, and K. Mohanan, "Microwave assisted synthesis, spectroscopic, thermal and biological studies of some lanthanide(III) chloride complexes with a heterocyclic schiff base," Synthesis and Reactivity in Inorganic, Metal-Organic and Nano-Metal Chemistry, vol. 39, no. 1, pp. 24–30, 2009.
35. M. Thankamony and K. Mohanan, "Synthesis, spectral studies, thermal decomposition kinetics, reactivity and antibacterial activity of some lanthanide(III) nitrate complexes of 2- (N-indole-2-one)amino-3-carboxyethyl-4,5,6,7-tetrahydrobenzo[b]thiophene," Indian Journal of Chemistry A, vol. 46, no. 2, pp. 247–251, 2007.
36. N. Raman, J. D. Raja, and A. Sakthivel, "Synthesis, spectral characterization of Schiff base transition metal complexes: DNA cleavage and antimicrobial activity studies," Journal of Chemical Sciences, vol. 119, no. 4, pp. 303–310, 2007.
37. B. Halli and V. B. Patil, "Synthesis, spectral characterization and DNA cleavage studies of Co(II), Ni(II), Cu(II), Zn(II), Cd(II) and Hg(II) complexes with benzofuran-2-carbohydrazide schiff bases," Indian Journal of Chemistry A, vol. 50, no. 5, pp. 664–669, 2011.
38. K. Shivakumar and M. B. Halli, "Synthesis, characterization and antimicrobial studies on metal complexes with a naphthofuran thiosemicarbazide derivatives," Journal of Coordination Chemistry, vol. 59, no. 16, pp. 1847–1856, 2006.
39. N. Bharti, S. Sharma, F. Naqvi, and A. Azam, "New palladium(II) complexes of 5-nitrothiophene-2-carboxaldehyde thiosemicarbazones: synthesis, spectral studies and in vitro anti-amoebic activity," Bioorganic & Medicinal Chemistry, vol. 11, no. 13, pp. 2923–2929, 2003.
40. A. A. Soliman, "Synthesis and properties of new substituted 1,2,4-triazoles: potential antitumor agents," Journal of Thermal Analytic Calculation, no. 63, p. 221, 2001.