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Chemical properties of thiadiazole compounds

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Abstract:

Heterocyclic compounds occur widely in nature and in a variety of non-naturally compounds, large number of heterocyclic compounds are essential to life such as alkaloids, antibiotics, essential amino acids, the vitamins, hemoglobin, hormones , a large number of synthetic drugs and dyes. Thiadiazole are very interesting compounds due to their important applications in many pharmaceutical biological and analytical fields.This review showed the optical , electrochemical properties , electrical conductivity and magnetic susceptibility for thiadiazole compounds .

Keywords : Heterocyclic compounds , thiadiazole compounds , chemical properties .

1-1: *Heterocyclic Compounds :*

A Heterocyclic are compounds with at least structure of one ring and a non-carbon atom.[1] The first series of heterocyclic compounds are three-member ring heterocycles containing single atoms of either, (O) (oxiridine) or (S) (thiirane) , (N) (azirine) in Figure (1- 1) (a). The four-member ring is observed in heterocyclic. The using of compounds as antibiotics such as cephalosporins and penicillin. Common examples are azetidine and dithiete in Figure (1) (b). Thietanes are used as fungicides and bactericides and also using in the production of polymers and inhibit iron corrosion [2]. The five-membered ring family represents an main segment of the heterocycles consisting of indoles, proline and hydroxyproline, which is a major constituent of collagen. The heme group related to myoglobin, hemoglobin and chlorophylls are all formed from Thiophene , furan and the pyrrole units of porphyrin in Figure (1)(c) are examples of five membered heterocycles containing sulfur and oxygen respectively.[2] As the size of ring increases, the number of derivatives increases because of varying the location possibility of the heteroatoms in the structures of the molecular. This research will make most use of the five-membered ring to benzene ring.

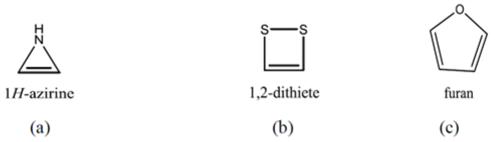


Figure (1-1) Examples of heterogeneous ring compounds

1-2.*Thiadiazole compounds :*

Thiadiazole is an main five heterocyclic ring compounds that containing two nitrogen atoms and one Sulphur atom. Thiadiazoles are an main type of heterocyclic compounds that exhibit diverse applications in organic induction, pharmaceutical and biological applications. They also known to useful as oxidation inhibitors, cyanine dyes, metal chelating agents, anti-corrosion agents[3][4]There are four isomeric classes depending on the situation of nitrogen atoms to each other : 1,2,3-thiadiazole; 1,3,4-thiadiazole; 1,2,4-thiadiazole and 1,2,5-thiadiazole as in the figure (1-2) [5].

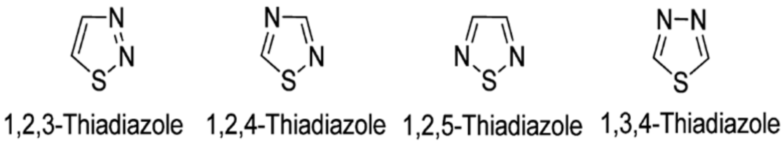


Figure (1-2) Isomers for thiadiazole compound

The curative importance of these rings prompted us to develop eclectic molecules in which a change could be considered in a pharmacological activity[6][7].

1-2-1. *Importanc in Chemistry :*

Thiadiazole showed entertaining optical, electronic, and chemical properties. It had been studied as an elegant candidate for organic bridging ligands to heteroatoms, N and S, with free electron pairs could device active coordination positions for metal ions or/and hydrogen-bond acceptors to expand polymeric frameworks. Moreover, introduction of amino/mercapto/hydroxyl substituents possessing tautomeric ability as well as some other common metal chelating ligands (such as phenyl, pyridyl[8][9], thiophene, etc.) can extend thiadiazole's approach into structure coordination chemistry. With the presence of conjugated π systems and the electron transfer between heteroatoms 31 (mainly N, S) and metal, the polymeric metal−organic frameworks with a thiadiazole component exhibited potential applications in catalysis, luminescence, magnetism, sorption, ion exchange, nonlinear optics, electricity, etc.[10][11] .

1-2-1-A. *Optical Importance :*

The derivative of thiadiazole containing synthesized vinyl, and their polymers which can emit heavy blue or green fluorescence have good solubility in CHCl3 or DMF.[12] The compounds coordination for transition metals with a 2,5-(R) thiadiazole derivative as the ligand exhibited a two-dimensional framework which further assembled into a three-dimensional supramolecular network via interlayer π−π-stacking interactions and strong hydrogen bonds, showing emitting blue photoluminescence in the solid state at room temperature[13]. Photo induced intermolecular charge transfer, the key to photoluminescence, needed a molecular assembly containing electron-donor units and electron-accepting units as well as an intermolecular π-conjugated structure. The aromatic thiadiazole ring derivative allows good π-electron conjugation and was demonstrated as a good candidate for its electron-withdrawing property[14-16]. It was also hypothesized that the luminance emission of the metal−thiadiazole network might be attributable to the intraligand transitions modulated by metal coordination and/or ligand-to-metal charge transfer (LMCT)[17].

Fluorescent chemosensors with their simplicity, high sensitivity, and fast response time have attracted enormous interest. With thiadiazoles as a fluorophore, the emitted fluorescence can be quenched or enhanced by a metal ion, suggesting that the metal−thiadiazole complexes can be used as metal-ion-selective sensors even via the naked eye detecting modes. In addition, these proposed methods can be tentatively utilized for 32 determination of heavy metal ions in tap water, river water, and industrial wastewater samples[18]. Cu2+ complexes derived from unsymmetric thiadiazoles exhibited mesogenic properties, and an excited-state intramolecular proton transfer (ESIPT) reaction in this type of o-hydroxy thiadiazole was also observed accompanied by the two phototautomer forms, enol and keto, coexisting in the excited state [19] .

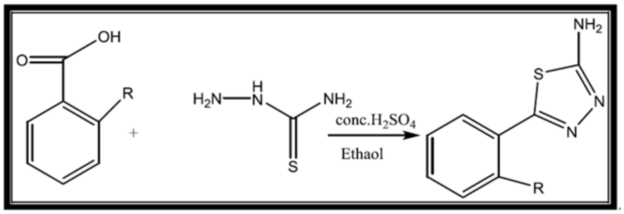
1-2-1-B. *Electrochemical Importance :*

With phenyl units and thiadiazole rings linked through acetylene groups, a π system extending throughout the molecular structure called a Poly (aryl-ethynylene) (PAE) system was obtained. Polymers involving this system showed rather low intramolecular reorganization energies and can be considered as candidates for n-type semiconductors.[10] 1,3,4-Thiadiazole-dithiolate/disulfide usually showed protoprotic tautomerism, acid−base equilibrium, and redox behavior based on a mercapto−disulfido conversion in the assembly reactions with metal ions, which were reportedly used as multidentate linkers or capacitance measurements in semiconductors.[20][21] An amperometric sensor with attractive sensing behavior was prepared using solid carbon paste as substrate for poly(2-amino-5-mercapto-1,3,4-thiadiazole) (AMT, PAMT) film.[22] In addition, the PAMT film was also used for selective determination of L-cysteine and folic acid[23] 2,5-Dimercapto-1,3,4-thiadiazole (DMcT) polymer PDMcT was also used to entrap a great deal of glucose oxidase GOx or tyrosinase and form PDMcT enzyme composites and then coelectro deposited with poly- (DMcT) on an Au electrode, which was demonstrated as sensitive glucose and phenolic biosensors[24]. In the currently decade, organosulfur-based compounds with multiple thiol groups or disulfide moieties have 33.

received attention as potential cathode electro active materials for lithium /lithium ion rechargeable batteries due to their high capacities to release and capture Lithium ions during charge/discharge cycles as well as the advantage of low cost. However, the sluggish kinetics of the redox reactions at room temperature, the lack of electronic conductivity, and the poor charge/discharge durability in liquid electrolyte systems made organo sulfur materials application limited. DMcT was reported as one of the most promising organo sulfur compounds as a cathode active material, and its redox reaction can be accelerated by the high electrocatalytic activity of the conducting polymers poly(3,4-ethylenedioxythiophene) (PEDOT),[24], [25] polypyrrole (Ppy), and polyaniline (PAn).[26], [27] Except for dye-sensitized solar cell, 1,3,4-thiadiazoles were also applied to form thin films of coordination complexes which had particular optical, electrical, magnetic, and catalytic properties.[28] In addition, two new perylene diimide derivatives obtained by functionalizing the basic perylene molecular core at imide nitrogen with thiadiazole rings made possible the fabrication of n-type organic thin-film transistors able to work in air[29].

1-3: *Importance of some Thiadiazole Derivatives :*

Remarkable progress has been made in the development of thiadiazole derivatives as shown in the equation (1-1) in the recent years and the most recent studies have revealed that thiadiazole derivatives have awide spectrum of pharmacological properties like, antimicrobial[30],[31] as the compounds shown in the figure (1-3) (a,b). anti-inflammatory[32],[33] such as the compounds shown in the figure (1-4)(a,b), anticancer[34][35] such as the compounds shown in the figure (1- 5) (a,b), antidiabetic activity [35],[36]such as the compounds shown in the figure (1-6) (a,b), antioxidant activity[37][38] anticonvulsant[39][40] such as the compounds shown in the figure (1-7) (a,b).Antitubercular activity[41] such as the compound shown in the figure (1-8) . Nataliya Zelisko *etal.* were syntheses thiopyrano[2,3-d][1,3]thiazole (2) and chromeno[4',3':4,5]thiopyrano[2,3-d]thiazole (3) derivatives [42] , Amal Hussein ,2019, prepared some new derivatives of thiadiazole [1, 4-bis ((2-(5-hydrazineyl-1, 3, 4-thiadiazol-2-yl) hydrazineylidene) methyl) benzene and (2,2'-((1,3,4-thiadiazole-2,5- diyl)bis(sulfanediyl))bis(N-(5-amino-4H-1,2,4-triazol-3-yl)acetamide) [43] .



…….(1-1)

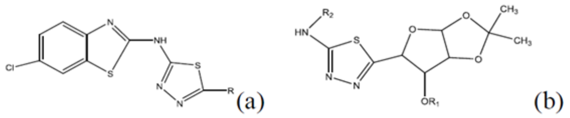


Figure (1-3) examples thiadiazole derivative biologically effective

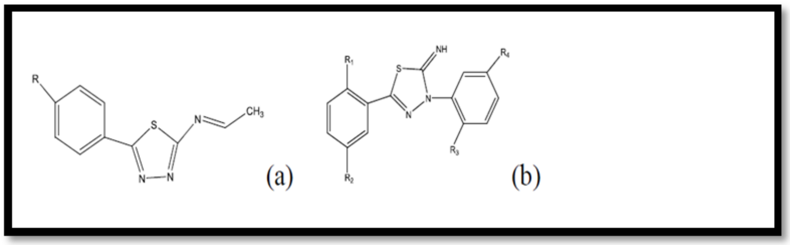


Figure (1-4) examples thiadiazole derivative anti-inflammatory effective

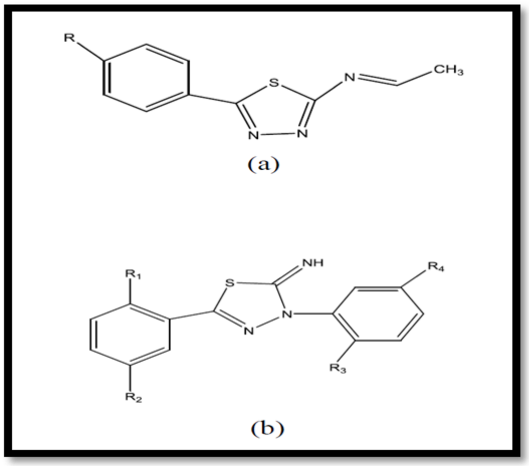


Figure (1-5) examples thiadiazole derivative anticancer effective

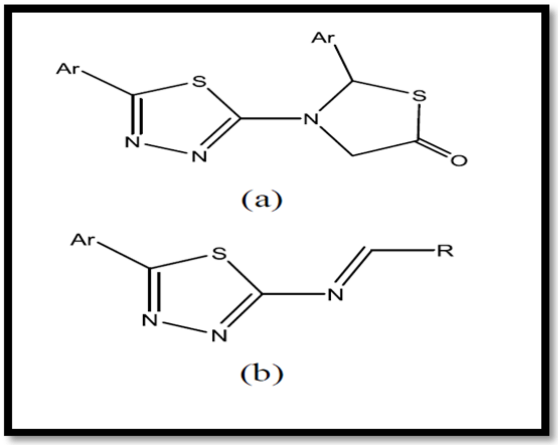


Figure (1-6) examples thiadiazole derivative antidiabetic activity effective

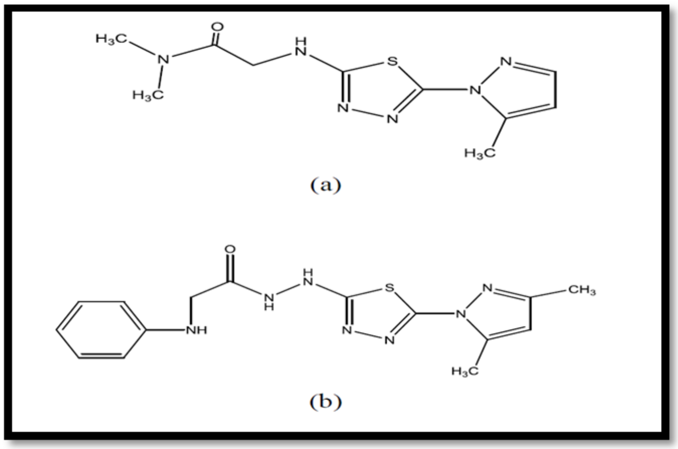


Figure (1-7) examples thiadiazole derivative (a) antioxidant and (b) anticonvulsant activity

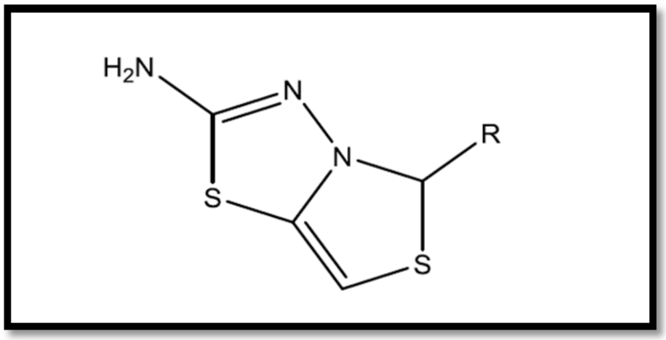


Figure (1-8) examples thiadiazole derivative Antitubercular effective

1-4: *Electrical Accessibility :*

Electrical accessibility in solid-phase materials is the process of moving charge carriers within the material under the influence of an electric field. These carriers may be electrons as in solid materials and metals or they are on Form ions as is the case in liquid solutions. In semiconductors conduction is accomplished via pair(Electron - hole) [44]. The organic semiconductor materials include polycyclic aromatic hydrocarbons (PAHs), metal complexes, and small compounds derived from conductive polymers such as polyacenes, polyphenylamines and polythiophenes [45][46].Organic semiconductors (OSCs) are known as organic π-conjugated materials with good charge transport and/or electroluminescent properties, and widely used in organic and hybrid electronic devices such as organic light emitting diodes (OLEDs), organic photovoltaic cells (OPVs) and organic field-effect transistors (OFETs)[47][48] .The relationships between molecular and supramolecular structures and the semiconducting properties of these materials have become crucial subjects over the past years; most of them concerning the evaluation of the band gap energy of OSCs[49][50]. In fact, the band gap energy denotes the energy separation between the 51 highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO), the analogues to the valence and conduction bands of the inorganic semiconductors (ISCs), respectively, and the molecular alignment and packing influences the HOMO and LUMO energy levels. The control of HOMO,LUMO energy gap of π- conjugated systems, and hence of the band gap of the corresponding materials, is a critical task for the semiconductor and nanomaterial industries [51][52]. The conducting properties of an OSC are dependent on the energy gap, and it is well-established that the band gap energy of insulators is larger than (>4 eV), but lower for semiconductors (<4 eV). The band-gap energy of organic π- conjugated semiconductors is related with the electronic band structure and depends on the pressure and temperature [53][54]. They tend to decrease with increasing Temperature due to increased atomic vibrations that lead to larger average interatomic spacing. The knowledge of the band gap is a major factor determining the electrical conductivity of a solid. It is of extremely fundamental in organic electronics, being decisive for choosing the OSC material for the manufacturing of stable and efficient Organic Light Emitting Diodes (OLEDs) and Organic Photo Voltaic cell s (OPVs). In these electronic devices, the efficiency of charge transport across the organic thin film layers plays a key role. Concerning the OLED devices, the charge injection process requires promotion of an electron or hole from the metal junctions into one of the charge transport states (HOMO for hole transport and LUMO for electron transport) of the organic thin film layers. It is desirable that the injected holes and electrons have both large and similar mobility, in order to recombine close to the electro luminescent layer and to prevent luminescence quenching close to the electrode's interface [55][56]. On the other hand, in OPVs, the charges created upon photoexcitation need to be efficiently transported and collected at the electrode's Contacts, and stored under 52.

The form of electrical energy. In OPVs the optical band gap limits the portion of the solar spectrum that is absorbed by the organic cell [57][58].

HOMO, LUMO gap energies can be experimentally measured by spectroscopic and conductivity methods. For instance, they can be derived from absorption and reflectance spectra, from electrical conductivity measurements and from photoconductivity techniques[59][60].

1-5: *Magnetic Sensitivity :*

The magnetic behavior of the materials varies depending on the number of individual electrons in the outer orbitals as well as on the distance between the atoms and the radius of the atom.

The magnetic spin moments contribution of the electron and the orbital moments of the magnetic moments express as the following equation [61]:

$$\mu_{S+L} = g\,[S(S+1)] + [1/4L(L+1)]\,1/2 \ldots\ldots\ldots\ldots (1)$$

Where:
μ =Total magnetic moments
g = gyromagnetic ratio
S = Total spin angular moment
L = Total orbital angular moment

The electronic structure determination that needs to take the round moment into consideration, it was found that when studying the transition metals complexes of the first-series have a very low angular orbital momentum contribution so this magnetic momentum is measuring only by spin angular moment relationship [61].

$$\mu_s = g\,[S(S+1)]\,1/2 \ldots\ldots\ldots\ldots (2)$$

The angular orbital moment for transition metals and lanthanides is significant take into consideration. Interest in the number of individual electrons is particularly important when studying the complexes of transitional metals . The μ values are change significantly with the change in the number of individual 54 electrons, the resulting error of taking the spin moment just a little consideration.

Then equation of the spin moment become

$$\mu_S = g\,[S(S+1)]\,1/2 = [4S(S+1)]\,1/2 \ldots\ldots\ldots\ldots (3)$$

Where ….
g = 2.00023 Bohr magnetons = 2
Since the
S=1/2, 1, 3/2, for non-duplex electrons, the equation is written as follows

$$\mu_s = [n(n+2)]\,1/2 \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where (n) is the number of non-duplex electrons and this equation is often used. [61]

Conclusion :

Thiadiazole showed interesting optical, electronic, and chemical properties. Thiadiazole exhibit diverse biological activities, possibly due the present of -N=C-S moiety. Thiadiazole are very interesting compounds due to their important applications in many pharmaceutical biological and analytical fields.

References:

[1] B. A. D. Neto, A. A. M. Lapis, E. N. da Silva Junior, and J. Dupont, “2, 1, 3-Benzothiadiazole and Derivatives: Synthesis, Properties, Reactions, and Applications in Light Technology of Small Molecules,” *European J. Org. Chem.*, vol. 2013, no. 2, pp. 228–255, 2013.

[2] F. E.-T. Heakal, A. S. Fouda, and S. S. Zahran, “Environmentally safe protection of carbon steel corrosion in sulfuric acid by thiouracil compounds,” *Int. J. Electrochem. Sci*, vol. 10, pp. 1595–1615, 2015.

[3] A. R. Katritzky, “Highlights from 50 years of heterocyclic chemistry,” *J. Heterocycl. Chem.*, vol. 31, no. 3, pp. 569–602, 1994.

[4] K. A. Kumar, P. Jayaroopa, and G. V. Kumar, “Comprehensive review on the chemistry of 1, 3, 4-oxadiazoles and their applications,” *Int. J. ChemTech Res.*, vol. 4, no. 4, pp. 1782–1791, 2012.

[5] A. Kumar, D. M. Lokeshwari, G. Pavithra, and V. Kumar, “1, 2, 4-Oxadiazoles: A potential pharmacological agents-An overview,” *Res. J. Pharm. Technol.*, vol. 5, no. 12, pp. 1490–1496, 2012.

[6] A. Foroumadi, S. Mansouri, Z. Kiani, and A. Rahmani, “Synthesis and in vitro antibacterial evaluation of N-[5-(5-nitro-2-thienyl)-1, 3, 4-thiadiazole-2-yl] piperazinyl quinolones,” *Eur. J. Med. Chem.*, vol. 38, no. 9, pp. 851–854, 2003.

[7] B. S. Holla, K. N. Poojary, B. S. Rao, and M. K. Shivananda, “New bis-aminomercaptotriazoles and bis-triazolothiadiazoles as possible anticancer agents,” *Eur. J. Med. Chem.*, vol. 37, no. 6, pp. 511–517, 2002.

[8] Y. Kobayashi, B. Jacobs, M. D. Allendorf, and J. R. Long, “Conductivity, doping, and redox chemistry of a microporous dithiolene-based metal− organic framework,” *Chem. Mater.*, vol. 22, no. 14, pp. 4120–4122, 2010.

[9] G.-L. Wen, Y.-Y. Wang, P. Liu, C.-Y. Guo, W.-H. Zhang, and Q.-Z. Shi, “A series of 1-D to 3-D metal–organic coordination architectures assembled with V-shaped bis (pyridyl) thiadiazole under co-ligand intervention,” *Inorganica Chim. Acta*, vol. 362, no. 6, pp. 1730–1738, 2009.

[10] J. M. Granadino-Roldán *et al.*, “Theoretical study of the effect of alkyl and alkoxy lateral chains on the structural and electronic properties of π-conjugated polymers consisting of phenylethynyl-1, 3, 4-thiadiazole,” *J. Phys. Chem. C*, vol. 115, no. 6, pp. 2865–2873, 2011.

[11] O. N. Trukhina *et al.*, “Scrutinizing the Chemical Nature and 178 Photophysics of an expanded hemiporphyrazine: The special case of [30] Trithia-2, 3, 5, 10, 12, 13, 15, 20, 22, 23, 25, 30-dodecaazahexaphyrin,” *J. Am. Chem. Soc.*, vol. 132, no. 37, pp. 12991–12999, 2010.

[12] Y. Tao, Q. Xu, J. Lu, and X. Yang, “The synthesis, electrochemical and fluorescent properties of monomers and polymers containing 2, 5-diphenyl-1, 3, 4-thiadiazole,” *Dye. Pigment.*, vol. 84, no. 2, pp. 153–158, 2010.

[13] K.-L. Zhang, N. Qiao, H.-Y. Gao, F. Zhou, and M. Zhang, “Self assembly of two novel three-dimensional supramolecular networks with blue photoluminescence,” *Polyhedron*, vol. 26, no. 12, pp. 2461–2469, 2007.

[14] T. Yasuda, T. Imase, Y. Nakamura, and T. Yamamoto, “New alternative donor− acceptor arranged poly (aryleneethynylene) s and their related compounds composed of five-membered electron-accepting

1, 3, 4-thiadiazole, 1, 2, 4-triazole, or 3, 4-dinitrothiophene units: synthesis, packing structure, and optical p," *Macromolecules*, vol. 38, no. 11, pp. 4687–4697, 2005.

[15] T. Yasuda, T. Imase, S. Sasaki, and T. Yamamoto, "Synthesis, solid structure, and optical properties of new thiophene-based alternating π-conjugated copolymers containing 4-alkyl-1, 2, 4-triazole or 1, 3, 4-thiadiazole unit as the partner unit," *Macromolecules*, vol. 38, no. 4, pp. 1500–1503, 2005.

[16] S. Fusco *et al.*, "NLO-active polymers containing triazolo-thiadiazole segments," *Polymer (Guildf).*, vol. 49, no. 1, pp. 186–191, 2008.

[17] W. Wei *et al.*, "Construction of a 2D luminescent network with a novel asymmetric flexible ligand involving unique octameric water clusters," *Inorg. Chem. Commun.*, vol. 12, no. 4, pp. 290–292, 179 2009.

[18] Y. Dong, B. Koken, X. Ma, L. Wang, Y. Cheng, and C. Zhu, "Polymer-based fluorescent sensor incorporating 2, 2′-bipyridyl and benzo [2, 1, 3] thiadiazole moieties for Cu2+ detection," *Inorg. Chem. Commun.*, vol. 14, no. 11, pp. 1719–1722, 2011.

[19] C.-T. Liao, Y.-J. Wang, C.-S. Huang, H.-S. Sheu, G.-H. Lee, and C. K. Lai, "New metallomesogens derived from unsymmetric 1, 3, 4-thiodiazoles: synthesis, single crystal structure, mesomorphism, and optical properties," *Tetrahedron*, vol. 63, no. 50, pp. 12437–12445, 2007.

[20] Z.-H. Li, P. Lin, and S.-W. Du, "Syntheses and characterization of three novel W (Mo)/Cu/S cluster-based layered polymers with 1, 3, 4-thiadiazole-2, 5-dithiolate(SSS): Intriguing coordination modes of SSS," *Polyhedron*, vol. 27, no. 1, pp. 232–240, 2008.

[21] F. M. Courtel, R. W. Paynter, B. Marsan, and M. Morin, "Synthesis, characterization, and growth mechanism of n-type CuInS2 colloidal particles," *Chem. Mater.*, vol. 21, no. 16, pp. 3752–3762, 2009.

[22] J.-B. He, F. Qi, Y. Wang, and N. Deng, "Solid carbon paste-based amperometric sensor with electropolymerized film of 2-amino-5-mercapto-1, 3, 4-thiadiazole," *Sensors Actuators B Chem.*, vol. 145, no. 1, pp. 480–487, 2010.

[23] P. Kalimuthu and S. A. John, "Nanostructured electropolymerized film of 5-amino-2-mercapto-1, 3, 4-thiadiazole on glassy carbon electrode for the selective determination of L-cysteine," *Electrochem. commun.*, vol. 11, no. 2, pp. 367–370, 2009.

[24] Y. Fu *et al.*, "Exploiting metal-organic coordination polymers as highly efficient immobilization matrixes of enzymes for sensitive electrochemical biosensing," *Anal. Chem.*, vol. 83, no. 17, pp. 180 6511–6517, 2011.

[25] S. E. Burkhardt, G. G. Rodríguez-Calero, M. A. Lowe, Y. Kiya, R. G. Hennig, and H. D. Abruna, "Theoretical and electrochemical analysis of poly (3, 4-alkylenedioxythiophenes): electron-donating effects and onset of p-doped conductivity," *J. Phys. Chem. C*, vol. 114, no. 39, pp. 16776–16784, 2010.

[26] E. Shouji, Y. Yokoyama, J. M. Pope, N. Oyama, and D. A. Buttry, "Electrochemical and Spectroscopic Investigation of the Influence of Acid− Base Chemistry on the Redox Properties of 2, 5-Dimercapto-1, 3, 4-thiadiazole," *J. Phys. Chem. B*, vol. 101, no. 15, pp. 2861–2866, 1997.

[27] R. A. Davoglio, S. R. Biaggio, R. C. Rocha-Filho, and N. Bocchi, “Bilayered nanofilm of polypyrrole and poly (DMcT) for high-performance battery cathodes,” *J. Power Sources*, vol. 195, no. 9, pp. 2924–2927, 2010.

[28] H. Gong, M. Yin, and M. Liu, “In situ coordination-induced langmuir film formation of water-soluble 2, 5-dimercapto-1, 3, 4-thiadiazole at the air/water interface and the growth of metal sulfide nanostructures in their templated Langmuir− Schaefer films,” *Langmuir*, vol. 19, no. 20, pp. 8280–8286, 2003.

[29] R. Centore *et al.*, “Perylene diimides functionalized with N-thiadiazole substituents: Synthesis and electronic properties in OFET devices,” *Org. Electron.*, vol. 13, no. 10, pp. 2083–2093, 2012.

[30] M. M. Raj, H. V Patel, L. M. Raj, and N. K. Patel, “Synthesis and biological evaluation of some new 1, 3, 4-thiadiazole derivatives 185 for their antimicrobial activities,” *Int. J. Pharm., Chem. Biol. Sci.*, vol. 3, pp. 814–819, 2013.

[31] S. M. Gomha and S. M. Riyadh, “Synthesis under microwave irradiation of [1, 2, 4] triazolo [3, 4-b][1, 3, 4] thiadiazoles and other diazoles bearing indole moieties and their antimicrobial evaluation,” *Molecules*, vol. 16, no. 10, pp. 8244–8256, 2011.

[32] S. J. Kashyap, V. K. Garg, P. K. Sharma, N. Kumar, R. Dudhe, and J. K. Gupta, “Thiazoles: having diverse biological activities,” *Med. Chem. Res.*, vol. 21, no. 8, pp. 2123–2132, 2012.

[33] A. K. Verma and A. Martin, “• SYNTHESIS, CHARACTERIZATION AND ANTI-INFLAMMATORY ACTIVITY OF ANALOGUES OF 1, 3, 4-THIADIAZOLE,” *Int. J. Pharm. Arch. ISSN 2319-7226*, vol. 3, no. 9, 2014.

[34] A. Naskar, T. Singha, T. Guria, J. Singh, A. B. Kumar, and T. K. Maity, “Synthesis, characterization and evaluation of anticancer activity of some new schiff bases of 1, 3, 4-thiadiazole derivatives,” *Int. J. Pharm. Pharm. Sci.*, vol. 7, no. 3, pp. 397–402, 2015.

[35] D. E. A. Rahman and K. O. Mohamed, “Synthesis of novel 1, 3, 4-thiadiazole analogues with expected anticancer activity,” *Der Pharma Chem.*, vol. 6, no. 1, pp. 323–335, 2014.

[36] P. A. Datar and T. A. Deokule, “Design and synthesis of thiadiazole derivatives as antidiabetic agents,” *Med chem*, vol. 4, no. 4, pp. 390–399, 2014.

[37] S. K. Chitale, B. Ramesh, C. M. Bhalgat, V. Jaishree, C. Puttaraj, and D. R. Bharathi, “Synthesis and antioxidant screening of some novel 1, 3, 4-thiadiazole derivatives,” *Res. J. Pharm. Technol.*, vol. 4, no. 9, pp. 1404–1408, 2011.

[38] B. K. Soni, T. Singh, C. M. Bhalgat, B. Kamlesh, S. M. Kumar, 186 and M. Pavani, “In-vitro antioxidant studies of some 1, 3, 4-thiadiazole derivatives,” *Int. J. Res. Phar. Biomed. Sci*, vol. 24, pp. 1590–1592, 2011.

[39] Z.-N. Cui *et al.*, “Synthesis and fungicidal activity of novel 2, 5-disubstituted-1, 3, 4-thiadiazole derivatives containing 5-phenyl-2-furan,” *Sci. Rep.*, vol. 6, p. 20204, 2016.

[40] M. S. Yar and M. W. Akhter, "Synthesis and anticonvulsant activity of substituted oxadiazole and thiadiazole derivatives," *Acta Pol. Pharm.*, vol. 66, no. 4, pp. 393–397, 2009.

[41] M. A. Rahman, A. K. Shakya, S. Wahab, and N. H. Ansari, "Synthesis of some new thiadiazole derivatives and their anticonvulsant activity," *Bulg. Chem. Commun.*, vol. 46, no. 4, pp. 750–756, 2014.

4.1 [42] *Nataliya Zelisko , Alexander V Karpenko , Volodymyr Muzychenko , Andrzej K. Gzella , Philippe Grellier and Roman Lesyk* **"***Trans -aconitic acid-based hetero -Diels-Alder reaction in the synthesis of thiopyrano[2,3- d][1,3]thiazole derivatives" Tetrahedron Letters ,V 58, Issue 18 , Pages 1751-1754 , 2017 .*

[43] Amal Hussein , "Preparation , characterization and electrical properties of some new ligands , PHD thesis, university of Thi-qar , Iraq , 2019 .

[44] C. Baker, W. Laminack, T. Tune, and J. Gole, "Magnetically induced enhancement of reversibly responding conductometric sensors," *J. Appl. Phys.*, vol. 115, no. 16, p. 164312, 2014.

[45] R. Podeszwa, "Interactions of graphene sheets deduced from properties of polycyclic aromatic hydrocarbons," *J. Chem. Phys.*, vol. 132, no. 4, p. 44704, 2010.

[46] Y. Hirose, A. Kahn, V. Aristov, P. Soukiassian, V. Bulovic, and S. R. Forrest, "Chemistry and electronic properties of metal-organic semiconductor interfaces: Al, Ti, In, Sn, Ag, and Au on PTCDA," *Phys. Rev. B*, vol. 54, no. 19, p. 13748, 1996.

[47]B. W. D'Andrade, A. Z. Kattamis, and P. F. Murphy, "Flexible organic electronic devices on metal foil substrates for lighting, photovoltaic, and other applications, S," *Handb. Flex. Org. Electron. Mater. Manuf. Appl.*, p. 315, 2014.

[48] G. H. Gelinck *et al.*, "Flexible active-matrix displays and shift registers based on solution-processed organic transistors," *Nat. Mater.*, vol. 3, no. 2, p. 106, 2004.

[49] V. Coropceanu and J. Cornil, "DAS Filho, Y. Olivier, R. Silbey, and J.-L. Brédas, "Charge Transport in organic semiconductors" ,*Chem. Rev*, vol. 107, p. 952, 2007.

[50] M. Y. Han, B. Özyilmaz, Y. Zhang, and P. Kim, "Energy band-gap engineering of graphene nanoribbons," *Phys. Rev. Lett.*, vol. 98, no. 20, p. 206805, 2007.

[51] G. Christou, "Single-molecule magnets: a molecular approach to nanoscale magnetic materials," *Polyhedron*, vol. 24, no. 16–17, pp. 2065–2075, 2005.

[52] M. C. Long, *Upper ocean physical and ecological dynamics in the* 192 *Ross Sea, Antarctica*. Stanford University, 2010.

[53] W. Bludau, A. Onton, and W. Heinke, "Temperature dependence of the band gap of silicon," *J. Appl. Phys.*, vol. 45, no. 4, pp. 1846–1848, 1974.

[54] C. Bohling and W. Sigmund, "Repulsive van der Waals forces self-limit native oxide growth," *Langmuir*, vol. 31, no. 17, pp. 4862–4867, 2015.

[55] X. Dai *et al.*, "Solution-processed, high-performance light-emitting diodes based on quantum dots," *Nature*, vol. 515, no. 7525, p. 96, 2014.

[56] J. Xie *et al.*, "Defect-rich MoS2 ultrathin nanosheets with additional active edge sites for enhanced electrocatalytic hydrogen evolution," *Adv. Mater.*, vol. 25, no. 40, pp. 5807–5813, 2013.

[57] Z. He *et al.*, "Simultaneous enhancement of open-circuit voltage, short-circuit current density, and fill factor in polymer solar cells," *Adv. Mater.*, vol. 23, no. 40, pp. 4636–4643, 2011.

[58] D. N. Congreve , J. Lee, "DN Congreve, J. Lee, NJ Thompson, E. Hontz, SR Yost, PD Reusswig, ME Bahlke, S. Reineke, T. Van Voorhis, and MA Baldo, Science 340, 334 (2013).," *Science (80-.).*, vol. 340, p. 334, 2013.

[59] W. Jin *et al.*, "Direct measurement of the thickness-dependent electronic band structure of MoS 2 using angle-resolved photoemission spectroscopy," *Phys. Rev. Lett.*, vol. 111, no. 10, p. 106801, 2013.

[60] B. Ketterer, M. Heiss, M. J. Livrozet, A. Rudolph, E. Reiger, and A. F. i Morral, "Determination of the band gap and the split-off band in wurtzite GaAs using Raman and photoluminescence excitation spectroscopy," *Phys. Rev. B*, vol. 83, no. 12, p. 125307, 193, 2011.

[61] Z. Szafran, R. M. Pike, and M. M. Singh, *Microscale inorganic chemistry: a comprehensive*