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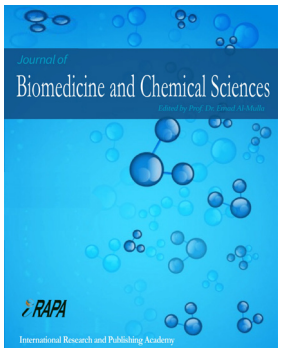

Synthesis, Characterization and Theoretical Study of 2,4-diaryl-1,3-Selenazole

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ABSTRACT

The synthesis of two new 2,4-diaryl-1,3-selenazoles series were achieved by subjecting primary arylselenocarboxylic amides to cyclization with α-bromoketones. The systematic preparation of 2,4-diaryl-1,3-selenazoles was carried out by the primary selenoamides with α-halo ketones. Selenoamides were obtained from the reaction of NaHSe with aryl nitrile .The resulting 2,4-diary-1,3-selenazoles have been characterized by different spectroscopic methods; such as 1H ,13C NMR, IR, and mass spectroscopic data to prove the structural formula of the prepared compounds. Theoretical study has been carried out by using DFT theory to study the structural and electronic properties of prepared compounds.

INTRODUCTION

Organo-selenium compounds have attracted increasing attention due to their diversities and wide applications in synthetic organic chemistry (Ranu & Banerjee, 2020; Wirth, 2003; Abdullah et al., 2020; Alsawad et al., (2021). 1,3-Selenazole moiety is a five-membered ring system containing two hetero atoms; selenium and nitrogen at the positions one and three in the ring, respectively. The chemistry involving heterocycles containing selenium has not advanced to the same extent as that of sulfur-containing heterocycles, primarily due to the pronounced toxicity and inherent instability associated with organo-selenium compounds (Sonawane & Koketsu, 2022; Jalbout et al., 2008; Jalbout et al., 2008).

Numerous synthetic pathways have been established to prepare derivatives of 1,3-selenazoles due to their distinct reactivity. One of the important synthesis methods is depending on the use of primary selenoureas and selenoamides (Tao et al., 2022; Hua et al., 2014). However, these important building blocks are not readily available and there are many disadvantages of known synthetic procedures (Geisler et al., 2002). 2,4-disubstituted-1,3-Selenazole were generally obtained by the reaction of Arylselenocarboxamide (Ar-(C=Se)NH_2) or selenourea(C=Se(NH_2)$_2$) with some nucleophiles (Koketsu & Ishihara, 2003). Reactions of primary selenocarboxamides with ketones, α-haloketones or haloacyl halides gave 2,4-diaryl-1,3-Selenazole derivatives (Tanini & Capperucci, 2020)

In our previous work, we have reported the cyclization of primary arylselenocarboxylic amides with α-bromoketones to afford a variety of new 2,4-diaryl-1,3-selenazoles. The biological activity of the prepared compounds has been investigated

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and they have indicated antiviral activity and some bioactivity against HIV-1 (Al-Rubaie et al., 2008).

In the present work, the reaction of pyridine-2-selenocarboxamide and pyridine-2-selenocarboxamide with α-bromoketones to prepare a variety of several unreported 2,4-diary-1,3-selenazoles. Also, the prepared derivatives of 1,3-selanazoles have been investigated theoretical by using the density functional theory (DFT) calculations at the hybrid Becke 3-Lee–Yang–Parr; B3LYP/3-21G level of theory to study their structural and electronic properties. Also, quantitative structure-activity relationship (QSAR) of the studied molecules have been investigated. All calculation has done using hyperchem program.

EXPERIMENT

Main Devices

^{1}H-NMR, ^{13}C-NMR spectra were recorded using a 400 MHz Bruker AVANCE NEO 400 spectrometer at the Department of Chemistry, College of Education for pure science, University of Basrah. They were recorded in DMSO-d_6 or $CDCl_3$ solutions containing TMS as internal standard. Chemical shifts for all ^{1}H and ^{13}C NMR spectra were reported in δ units downfield from internal reference Me_4Si.

Synthesis

All reactions were performed under Argon atmosphere. All solvents were dried and freshly distilled under Argon before use. Pyridine-2-selenocarboxamide and pyridine-2-selenocarboxamide were prepared according to the literature method (Al-Rubaie et al., 2002):

$NaBH_4$ (2.02g; 53.75mmol) was added portion-wise over 30 min to a suspension of Se powder (3.95g; 50 mmol) in (50ml) ethanol under Argon atmosphere while hydrogen evolved vigorously. The resulting solution was stirred for a further 15 min. Pyridine (8.1ml; 100mmol) and corresponding nitrile (20mmol) in ethanol (25 ml) were then added to NaHSe. Then, the solution was heated under reflux while HCl (35ml; 2M) was added dropwise over 3h. The resulting solution was refluxed for an additional 30 min then allowed to cool to room temperature. After that, the saturated aqueous solution of Na_2CO_3 (25ml) and H_2O (50 ml) were added. The resulting solution was extracted with CH_2Cl_2 (3x50 ml). The combined extracts were dried over Na_2SO_4 and the solvent was evaporated. An air-sensitive crude product was then isolated as pale yellow.

2,4-Diary-1,3-selenazoles were prepared from the reaction of the corresponding aryl selenocarboxamides with α-bromoketones (2-bromo-1-pyridin-2-yl-ethanone, 2-bromo-1-pyridin-3-yl-ethanone and 2-Bromo-4′-phenylacetophenone) by the following general procedure: A solution of α-bromoketones (10 mmol) in 10 cm^3 of ethanol was added dropwise to a hot solution of arylselenocarboxamides (10 mmol) in 20 cm^3 ethanol. The reaction mixture was refluxed for 45-60 min (the end of the reaction was monitored by TLC using ethyl acetate and n-hexane as eluent). The mixture is then concentrated by a rotary evaporator and the residue neutralized with dilute aqueous ammonia (10%). The precipitate is deposited, collected by filtration and then washed several times with cold ethanol. Recrystallization from ethanol to give the corresponding 2,4-diary-1,3-selenazoles in fair to good yields.

2-(pyridin-2-yl)-4-(pyridin-3-yl)-1,3-selenazole (1)

Yield:74% . M.p. 131-331ºC, ^{1}H NMR ($CDCl_3$): δ 9.22 (d, J = 2.3 Hz, 1H; H13), 8.58 (dt, J = 4.7, 2.7 Hz, 2H; H5,15), 8.29 (s, 1H; H10), 8.28 – 8.24 (m, 2H; H3,17), 7.80 (td, J = 7.7, 1.7 Hz, 1H, H2), 7.35 (dt, J = 8.2, 4.4 Hz, 2H; H4,16). ^{13}C NMR ($CDCl_3$): δ 176.86; C7, 154.49; C9,152.94; C1, 149.73; C13,148.83; C5,148.02; C15,137.12; C17,133.77; C3, 131.33; C12,124.93; C2, 123.57; C16, 122.21; C4, 118.94; C10.MS: m/z: 287(M^+).

2-(pyridin-2-yl)-4-(thiophen-2-yl)-1,3-selenazole (2)

Yield:66% . M.p. 98-100 ºC, ^{1}H NMR (DMSO-d6): 8.64 (d, J = 4.7 Hz, 1H; H8), 8.58 (s, 1H; H4), 8.14 (d, J = 7.9 Hz, 1H; H11), 8.00 (t, J = 7.8 Hz, 1H; H10), 7.63 (d, J = 3.6 Hz, 1H; H15),7.55 (t, J = 5.5 Hz, 2H; H13,14), 7.14 (t, J = 4.3 Hz, 1H; H9). ^{13}C NMR (DMSO-d6): δ 176.25; C1, 152.31; C3, 151.65; C6, 150.57; C8, 139.41; C10,138.46; C12, 128.60; C15,126.41; C13 126.10; C14,124.81; C11, 121.46; C9, 118.77; C4. MS: m/z: 292(M^+).

4-([1,1'-biphenyl]-4-yl)-2-(pyridin-2-yl)-1,3-selenazole (3)

Yield:91% . M.p. 185-186 ºC, ^{1}H NMR (DMSO-d6): δ 8.83 (s, 1H; H14), 8.66 (d, J = 4.8 Hz, 1H; H22),8.26 (d, J = 7.8 Hz, 1H; H19), 8.16 (d, J = 8.2 Hz, 2H; H9,11), 8.01 (td, J = 7.7, 1.7 Hz, 1H; H20), 7.78 (d, J = 8.1 Hz, 2H; H8,12), 7.74 (d, J = 7.1 Hz, 2H; H3,5), 7.55 (dd, J = 7.5, 4.9 Hz, 1H; H21), 7.49 (t, J = 7.6 Hz, 2H, 2,6), 7.39 (t, J = 7.3 Hz, 1H; H1). ^{13}C NMR (DMSO-d6) δ: 176.02; C16, 156.52; C13, 152.64; C18, 150.54; C22, 140.04; C10, 139.95; C7, 138.41; C20, 134.54; C4, 129.48; C2,6, 128.06; C1, 127.54; C8,12, 127.32; C9,11, 127.04; C3,5 126.01; C19, 123.47; C21, 118.90; C14. m/z: 362(M^+).

2,4-di(pyridin-3-yl)-1,3-selenazole (4)

Yield:77% . M.p. 108-110 ºC. ^{1}H NMR ($CDCl_3$): δ 9.20 (s, 1H; H13), 9.17 (s, 1H. H11), 8.69 (d, J = 4.7 Hz, 1H, H15), 8.59 (d, J = 4.7 Hz, 1H; H9), 8.34 – 8.21 (m, 3H, H4,7,17), 7.39 (dt, J = 8.7, 4.4 Hz, 2H, H8,16). ^{13}C NMR ($CDCl_3$) δ: 171.16; C1, 154.35; C3, 151.34; C13, 149.20; C11, 148.39; C15, 148.13; C9, 134.16; C17, 134.05; C7, 132.12; C12, 130.94; C6, 123.99; C16, 123.77; C8, 120.56; C4. m/z: 362(M^+).

2-(pyridin-3-yl)-4-(thiophen-2-yl)-1,3-selenazole (5)

Yield:60% . M.p. 58-60 ºC. ^{1}H NMR (DMSO-d6): δ 9.15 (s, 1H; H12), 8.68 (d, J = 4.6 Hz, 1H, H14), 8.27 (d, J = 7.9 Hz, 1H; H16), 8.02 (s, 1H, H7), 7.51 (d, J = 3.5 Hz, 1H, H4), 7.39 (dd, J = 7.9, 4.9 Hz, 1H; H15), 7.31 (d, J = 5.0 Hz, 1H; H2), 7.08 (t, J = 4.3 Hz, 1H; H3). ^{13}C NMR (DMSO-d6) δ|: 170.43; C9, 151.91; C6, 151.19; C12, 148.39; C14, 139.12; C5, 134.05; C16, 132.11; C11, 127.90; C15, 125.63; C4, 124.55; C2, 123.94; C3, 117.60; C7. m/z: 292(M^+).

4-([1,1'-biphenyl]-4-yl)-2-(pyridin-3-yl)-1,3-selenazole (6)

Yield:88% . M.p. 173-175 ºC. ^{1}H NMR (DMSO-d6): δ 9.23 (d, J = 2.3 Hz, 1H; H23), 8.84 (s, 1H; H14), 8.71 (dd, J = 4.8, 1.6 Hz, 1H; H21), 8.40 (dt, J = 8.1, 2.2 Hz, 1H; H19), 8.16 (d, J = 8.2 Hz, 2H; H9,11), 7.78 (d, J = 8.2 Hz, 2H; 8,12), 7.74 (d, J = 7.7 Hz, 2H; 3,5),7.56 (dd, J = 8.0, 4.8 Hz, 1H; H20), 7.49 (t, J = 7.6 Hz, 2H; H2,6), 7.39 (t, J = 7.3 Hz, 1H; H1) . ^{13}C NMR (DMSO-d6) δ: 170.25; C16, 155.50; C13, 151.19; C23 147.45; C21, 139.64; C10, 139.61; C7, 134.20; C4, 133.82; C19, 131.68; C18, 129.07; C2,6, 127.68; C1, 127.15; C8,12, 127.08; C9,11, 126.64; C3,5, 124.44; C20, 122.18; C14. m/z: 362(M^+).

RESULTS & DISCUSSION

In this work, two arylselenocaboxamides pyridine-2-selenocarboxamide and pyridine-2-selenocarboxamide have been selected to be reacted with α-bromoketones to prepare a variety of several unreported 2,4-diary-1,3-selenazoles. Each arylselenocaboxamides has been reacted with 2-bromo-1-pyridin-2-yl-ethanone, 2-bromo-1-pyridin-3-yl-ethanone and 2-Bromo-4′-phenylacetophenone respectively to give the corresponding 2,4-diaryl-1,3-selenazoles in good yields (Experimental section).

The mechanism of reaction is shown in Scheme 1. As shown in this scheme initially, intermediate A forms through the combination of selenoamides and α-halo ketones. This intermediate then proceeds with the cyclization process, yielding another intermediate; B. Subsequently, intermediate B undergoes a reaction in which it loses a molecule of H_2O, ultimately giving rise to the synthesis of 2,4-diary-1,3-selenazoles (1-6). All prepared selenazole compounds in the series (1-6) exists as a crystalline solid, ranging in color from yellow to white, and possesses a distinct and well-defined melting point. 2,4-diaryl-1,3-selenazoles exhibit remarkable stability, remaining unaffected by exposure to air or moisture for extended periods, with no observable signs of deterioration, such as the development of a reddish hue in the powders or the release of elemental selenium, which is often accompanied by the emission of a noxious odor. These compounds exhibit solubility in commonly used organic solvents.

The IR spectra of all prepared compounds indicate an absorption band between 1580-1630 cm^{-1} due to ν(C=N) and an absorption band in range 595-560 cm^{-1} may assigned to ν(Se-C) bond. ^{1}H NMR spectra of compounds 1-6 were recorded in DMSO-d6 and provided further evidence for the formation of these compounds; see Table 1. The ^{1}H-NMR spectra exhibit the expected peaks including sharp singlet signals between 8.02 and 8.84 ppm assigned to the only proton of the 1,3-selenazole rings. Thus, it may be concluded that as the s character increase in sp^2, bonding electrons move closer to carbon thereby deshielding the protons.

This result is supported by the literature data (Etesam et al., 2022; Hua et al., 2018). A singlet to multiplet signal appears at the range 7.07-9.23 ppm for the aromatic protons (Experimental section). The structural characterization of the selenazoles was corroborated using ^{13}C-NMR data, which were consistent with previously reported values (Alias et al., 2020; Dzedulionytė et al., 2021); see Table 2. The ^{13}C-NMR spectra of the newly synthesized selenazoles rings were recorded in either CDCl3 or DMSO-d6 (see experimental section and supporting data). These spectra exhibited three distinctive signals characteristic of the 1,3-selenazole rings, in addition to the anticipated signals arising from the aromatic carbon frameworks. Specifically, the Se-C=N signal of the selenazole ring was observed in the downfield region, ranging from 170.25 to 178.76 ppm, while the C-Se signal appeared in the upfield region, spanning from 117.60 to 127.32 ppm. This shift in chemical shift can be attributed to the shielding effect imparted by the selenium atom. Signals corresponding to aromatic substituents within the selenazole ring were detected in the range of 121.46 to 152.94 ppm.

To get more insight about the structural and

electronic properties of the prepared molecules of 2,4-diaryl-1,3-Selenazole, theoretical study has been carried out using DFT at the at the B3LYP/3-21G level of the theory. Figure 1 presents the geometrical structures of the 2,4-diaryl-1,3-Selenazoles, which were optimized using the B3LYP/3-21G level of theory. These optimized structures are crucial for examining the geometric characteristics of the studied molecules and providing insights into their point groups. Optimizing the structures is a fundamental prerequisite for conducting subsequent meaningful calculations. Some of the selected structural parameters of the studied molecules are depicted in Figure 1.

The optimized structure of studies selenazole derivatives (1-6) indicated that the five membered of selenazole Se(1)-C(2)-N(3)-C(4)-C(5) have planar conformation. The calculated Se(1)-C(2) and Se(1)-C(5) bonds distances in 1-6 studied molecules are 1.891 Å and 1.883_Å respectively. The calculated Se-C bonds are slightly shorter than what one might anticipate based on the conventional C-Se single-bond lengths, which typically fall within the range of approximately 1.92 to 1.94 Å (Beswick et al., 1999). On the other hand, the calculated angle of C(5)-Se(1)-C(2) vary from 80.76-81.08, whereas C(2)-N(3)-C(4) vary from 112.73-113.61. The calculated angle of C–Se–C in the studied molecules are thoughtfully less than that in the stated similar structure [83.3(5)°], (Al-Rubaie et al., 2008) and that in 1,3,4-selenadiazoles [81.9(4)–82.7(2)°], (Hua et al., 2009; Li et al., 2009; Cordes et al., 2011) and meaningfully smaller than that in the 2,5-diarylselenophenes [87.8(8)°], (Hua et al., 2010) demonstrating the size arrangement for the C–Se–C angles in the five membered ring systems being: 2,5-diarylselenophenes > 1,3- selenazoles > 1,3,4-selenadiazoles. The calculated bonds length of C=N and C-N are 1.348 and 1.351 respectively. These experimental reported values of the same bonds in 1,3-selenazoles are [1.268(11) Å for C=N bond and 1.384(11) Å for C–N bond] (Al-Rubaie et al., 2008).

Table 3 shows the highest occupied and the lowest unoccupied molecular orbital energies (HOMO and LUMO, respectively), and the frontier molecular orbital energy gap (HOMO–LUMO energy difference, ΔE). It can be seen clearly form scheme 1, the main difference between studied 1,3-selenazoles is the position of nitrogen atom in 2-aryl moiety, where in in 1-3 molecules the nitrogen atom is located at position 2, whereas in 4-6 molecules the nitrogen atom is located at position 3. Thus, there is no significant structural changes in the studied molecules, consequently, this may be led to not systematic change in the values of the HOMO and LUMO levels for the studied molecules.

Table 4 displays a subset of the chosen QSAR properties for the studied molecules. The patterns in surface area and volume values are readily discernible, considering that the molecules 3 and 6 exhibits higher surface and volume values, it's evident that this is attributed to the presence of a biphenyl moiety, which occupies a larger surface area and volume. The total volume of the studied molecules varies from 663.83 to 913.07 $Å^3$. The log P magnitude of a compound is derived by taking the base-10 logarithm of its partition coefficient (P), which represents the ratio of the compound's concentrations in an organic (oil) phase to that in an aqueous phase. Nevertheless, the computed log P value for a compound in water, as opposed to a simpler organic compound such as octanol or hexane, can serve as a useful indicator for predicting its solubility behavior in various aqueous and organic solvents.

The log P value for a compound is the logarithm (base 10) of the partition coefficient (P), which is defined as the ratio of the compound's organic (oil)-to-aqueous phase concentrations. However, the calculated log P value for a compound in water vs. a simple organic compound like octanol or hexane can provide a guideline for predicting its solubility characteristics in other aqueous and organic solvents (Hansch & Leo, 1995; Atkins, 2010). These magnitudes typically align with the categorization of compounds based on their water-solubility and membrane-permeability characteristics. For instance, if a molecule possesses a calculated log P value of 1, it signifies that its concentration ratio in the organic phase to the aqueous phase is 10:1. This implies that the molecule is hydrophobic and likely to exhibit greater solubility in organic solvents. Conversely, if the molecule has a calculated log P value of -1, it indicates a concentration ratio of 1:10 in the organic phase to the aqueous phase, signifying that the molecule is hydrophilic and more likely to be soluble in an aqueous buffer. The calculated log P magnitudes of the studied 1,3-selenazole molecules are 1.68, -0.09,3.75, 1.75, -0.02 and 3.82 respectively. The result indicates that 2 and 5 molecules may be poorly soluble in water, while the 1,3,4 and 6 molecules of the two series are readily soluble in water or aqueous buffers. In other words, these findings suggest that 1,3-selenazole 2 and 5 could be hydrophilic and potentially dissolve in an aqueous buffer.

The calculated refractivity and polarizability the 1, 2, 4 and 5 have shown almost similar values for each one of them. The 3 and 6 molecules indicate

larger values. This means that the structural change of the biphenyl moiety has considerable effect on the theoretical refractivity and polarizability values for the 3 and 6 molecules. The three-dimensional mapped is surface depicting the electrostatic potential of the investigated molecules are presented in Figure 2. This plot offers insights into the reactivity of the molecules in real reactions involving electrophiles or nucleophiles. Negative ESP regions are represented by dark (violet) colors, while positive ESP regions are depicted by light (green) colors. For all studied molecules, the plots show that the nitrogen atoms of the 2,4-diaryl-1,3-Selenazole have the maximum negative ESP region and the aryl and five membered rings have the minimum negative ESP regions. This indicates that the most reactive site on the studied molecules are nitrogen atoms, which afford the formation of physical bond with the active sites of ammino acid. Furthermore. The ESP plots show that the selenium atoms have positive ESP regions. Such conclusions are important in understanding the physical properties of the studied molecules. These findings hold significance in grasping the physical characteristics of the examined molecules.

CONCLUSION

Two series of 2,4-diaryl-1,3-Selenazole have been synthesized by the reaction of pyridine-2-selenocarboxamide and pyridine-2-selenocarboxamide with α-bromoketones. The resulting molecules have been characterized by different spectroscopic method; such as 1H, and 13C NMR, all analysis confirm the formation of 2,4-diaryl-1,3-Selenazole molecules. The prepared derivatives of 2,4-diaryl-1,3-Selenazole have been investigated theoretical by using the density functional theory (DFT) calculations at the hybrid Becke 3-Lee–Yang–Parr; B3LYP/3-21G level of theory to study their structural and electronic properties. Also, quantitative structure-activity relationship (QSAR) of the studied molecules have been investigated. All calculation has done using hyperchem program.

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Competing Interest

The authors had no competing interests.

REFERENCES

[1] Abdullah, S. A., Ali, D. S., & Hameed, A. J. (2020). A study of the biological activity of 4-(Para-Substituted phenyl)-1, 2, 3-Selenadiazole derivatives as anti-oxidant and anti-breast cancer. *Basrah Journal of Science, 38*(3), 480-496.

[2] Alias, N. Z., Idris, M. H. M., Somat, N. A., Mahmud, N., Hasan, S., Lam, K. W., ... & Hassan, N. I. (2020). Synthesis, antioxidant, anticholinesterase activities and molecular docking studies of coumaryl 1, 3-selenazoles derivatives. *Preprints.*

[3] Al-Rubaie, A. Z., Al-Masoudi, W. A., Hameed, A. J., Yousif, L. Z., & Graia, M. (2008). Synthesis, reaction and antiviral activity of 2, 4-diaryl-1, 3-selenazoles. *Journal of the Korean Chemical Society, 52*(1), 36-46.

[4] Al-Rubaie, A. Z., Yousif, L. Z., & Al-Hamad, A. J. (2002). Palladium-catalyzed formation of 3, 5-diaryl-1, 2, 4-selenadiazoles from arylselenocarboxamide. *Journal of Organometallic Chemistry, 656*(1-2), 274-280. https://doi.org/10.1016/S0022-328X(02)01631-5

[5] Alsawad, D. H., Al-Riyahee, A. A., & Hameed, A. J. (2021, November). Simulation Study of Structural and Electronic Properties for Adducts complexes of Bis (Acetylacetonato) oxoVandium (IV) with 4-(Para-substituted phenyl)-1, 2, 3-Selenadiazole. In *Journal of Physics: Conference Series* (Vol. 2063, No. 1, p. 012002). IOP Publishing. https://doi.org/10.1088/1742-6596/2063/1/012002

[6] Atkins, P. (2010). *Shriver and Atkins' inorganic chemistry*. Oxford University Press, USA.

[7] Beswick, M. A., Harmer, C. N., Raithby, P. R., Steiner, A., Tombul, M., & Wright, D. S. (1999). Reactions of organolithium complexes with elemental selenium: insertion producing [PhC CSeLi· TMEDA· THF] 1 and cyclisation producing [{PhC} 4Se] 2 (TMEDA=[Me2NCH2] 2). *Journal of organometallic chemistry, 573*(1-2), 267-271. https://doi.org/10.1016/S0022-328X(98)00830-4

[8] Cordes, D. B., Hua, G., Slawin, A. M., & Woollins, J. D. (2011). 2, 5-Diaryl-1, 3, 4-selenadiazoles prepared from Woollins' reagent. *Crystal Structure Communications, 67*(12), o509-o514. https://doi.org/10.1107/S0108270111049900

[9] Dzedulionytė, K., Voznikaitė, P., Bieliauskas, A., Malinauskienė, V., Sløk, F. A., & Šačkus, A. (2021). Methyl 2-amino-4-[1-(tert-butoxycarbonyl) azetidin-3-yl]-1, 3-selenazole-5-carboxylate. *Molbank, 2021*(2), M1207. https://doi.org/10.3390/M1207

[10] Etesam, L., Mosslemin, M. H., & Hassanabadi, A. (2022). A simple, one-pot method for the synthesis of functionalized selenazole derivatives. *Phosphorus, Sulfur, and Silicon and the Related Elements, 197*(12), 1273-1276. https://doi.org/10.1080/10426507.2022.2096609

[11] Geisler, K., Jacobs, A., Künzler, A., Mathes, M., Girrleit, I., Zimmermann, B., ... & Langer, P. (2002). Efficient synthesis of primary selenocarboxylic amides by reaction of nitriles with phosphorous (V) selenide. *Synlett, 2002*(12), 1983-1986. https://doi.org/10.1055/s-2002-35604

[12] Hansch, C., & Leo, A. (1995). *Exploring quantitative structure-activity relationships (QSAR); Fundamentals and applications in chemistry and biology*. American Chemical Society.

[13] Hua, G., Cordes, D. B., Du, J., Slawin, A. M., & Woollins, J. D. (2018). Diverse derivatives of selenoureas: A synthetic and single crystal structural study. *Molecules, 23*(9), 2143. https://doi.org/10.3390/molecules23092143

[14] Hua, G., Du, J., Slawin, A. M., & Woollins, J. D. (2014). A synthetic and structural study of arylselenoamides and 2, 4-diaryl-1, 3-selenazoles. *Synlett, 25*(15), 2189-2195. https://doi.org/10.1055/s-0034-1378525

[15] Hua, G., Henry, J. B., Li, Y., Mount, A. R., Slawin, A. M., & Woollins, J. D. (2010). Synthesis of novel 2, 5-diarylselenophenes from selenation of 1, 4-diarylbutane-1, 4-diones or methanol/arylacetylenes. *Organic & Biomolecular Chemistry, 8*(7), 1655-1660. https://doi.org/10.1039/B924986A

[16] Hua, G., Li, Y., Fuller, A., Slawin, A. M. Z., & Woollins, J. D. (2009). Facile synthesis and structure of novel 2, 5-disubstituted 1, 3, 4-selenadiazoles. *European Journal of Organic Chemistry, 2009*(10), 1612-1618. https://doi.org/10.1002/ejoc.200900013

[17] Jalbout, A. F., Hameed, A. J., & Essa, A. H. (2008). Structural isomers of 2-(2, 3 and 4-substituted-phenyl)-1, 2-benzisoselenazol-3 (2H)-one: A Theoretical Study. *Journal of Organometallic Chemistry, 693*(12), 2074-2078. https://doi.org/10.1016/j.jorganchem.2008.02.026

[18] Jalbout, A. F., Hameed, A. J., Jimenez-Fabian, I., Ibrahim, M., & De Leon, A. (2008). Chalcanthrene–fullerene complexes: A theoretical study. *Journal of Organometallic Chemistry, 693*(2), 216-220. https://doi.org/10.1016/j.jorganchem.2007.09.036

[19] Koketsu, M., & Ishihara, H. (2003). Synthesis of 1, 3-selenazine and 1, 3-selenazole and their biological activities. *Current Organic Chemistry, 7*(2), 175-185. https://doi.org/10.2174/1385272033373102

[20] Li, Y., Hua, G. X., Slawin, A. M., & Woollins, J. D. (2009). The X-ray crystal structures of primary aryl substituted selenoamides. *Molecules, 14*(2), 884-892. https://doi.org/10.3390/molecules14020884

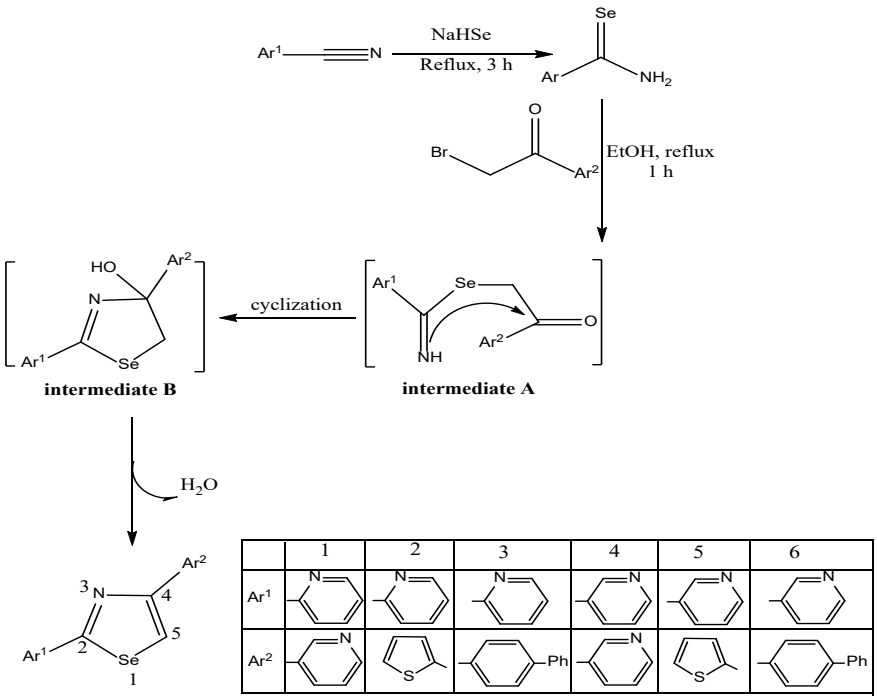
[21] Ranu, B. C., & Banerjee, B. (Eds.). (2020). *Organoselenium Chemistry.* Walter de Gruyter GmbH & Co KG.

[22] Sonawane, A. D., & Koketsu, M. (2022). 1, 3-Selenazoles. *Comprehensive Heterocyclic Chemistry IV.* https://doi.org/10.1016/B978-0-12-818655-8.00089-5

[23] Tanini, D., & Capperucci, A. (2020). Recent advances in the synthesis of five-and six-membered selena-heterocycles. *Target in heterocyclic systems: chemistry and properties, 2020,* 289-319.

[24] Tao, S., Xu, L., Yang, K., Zhang, J., & Du, Y. (2022). Construction of the 2-amino-1, 3-selenazole skeleton via PhICl2/KSeCN-mediated selenocyanation/cyclization. *Organic Letters, 24*(23), 4187-4191. https://doi.org/10.1021/acs.orglett.2c01468

[25] Wirth, T. (2003). Introduction and general aspects. *Hypervalent Iodine Chemistry: Modern Developments in Organic Synthesis*, 1-4. https://doi.org/10.1007/3-540-46114-0_1



Scheme 1. Synthesis of 2,4-diaryl-1,3-Selenazole (1-6)

Table 1
[1]HNMR spectral data of 2,4-diaryl-1,3-Selenazole

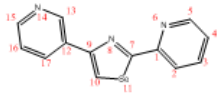
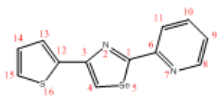
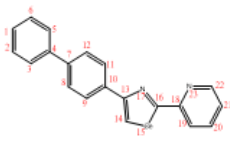
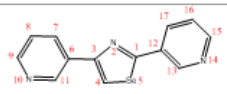
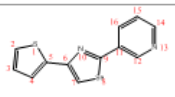
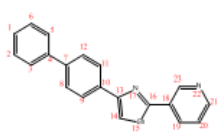
Comp	Structure	Chemical shift (ppm)
1		9.22 (d, J = 2.3 Hz, 1H; H13) 8.58 (dt, J = 4.7, 2.7 Hz, 2H; H5,15) 8.29 (s, 1H; H10) 8.28 – 8.24 (m, 2H; H3,17) 7.80 (td, J = 7.7, 1.7 Hz, 1H, H2) 7.35 (dt, J = 8.2, 4.4 Hz, 2H; H4,16)
2		8.64 (d, J = 4.7 Hz, 1H; H8); 8.58 (s, 1H; H4) 8.14 (d, J = 7.9 Hz, 1H; H11) 8.00 (t, J = 7.8 Hz, 1H; H10) 7.63 (d, J = 3.6 Hz, 1H; H15) 7.55 (t, J = 5.5 Hz, 2H; H13,14) 7.14 (t, J = 4.3 Hz, 1H; H9)
3		8.83 (s, 1H; H14) 8.66 (d, J = 4.8 Hz, 1H; H22) 8.26 (d, J = 7.8 Hz, 1H; H19) 8.16 (d, J = 8.2 Hz, 2H; H9,11) 8.01 (td, J = 7.7, 1.7 Hz, 1H; H20) 7.78 (d, J = 8.1 Hz, 2H; H8,12) 7.74 (d, J = 7.1 Hz, 2H; H3,5) 7.55 (dd, J = 7.5, 4.9 Hz, 1H; H21) 7.49 (t, J = 7.6 Hz, 2H, 2,6) 7.39 (t, J = 7.3 Hz, 1H; H1)
4		9.20 (s, 1H; H13), 9.17 (s, 1H. H11), 8.69 (d, *J* = 4.7 Hz, 1H, H15), 8.59 (d, *J* = 4.7 Hz, 1H; H9), 8.34 – 8.21 (m, 3H, H4,7,17), 7.39 (dt, *J* = 8.7, 4.4 Hz, 2H, H8,16).
5		9.15 (s, 1H; H12), 8.68 (d, *J* = 4.6 Hz, 1H, H14), 8.27 (d, *J* = 7.9 Hz, 1H; H16), 8.02 (s, 1H, H7), 7.51 (d, *J* = 3.5 Hz, 1H, H4), 7.39 (dd, *J* = 7.9, 4.9 Hz, 1H; H15), 7.31 (d, *J* = 5.0 Hz, 1H; H2), 7.08 (t, *J* = 4.3 Hz, 1H; H3).
6		9.23 (d, J = 2.3 Hz, 1H; H23) 8.84 (s, 1H; H14) 8.71 (dd, J = 4.8, 1.6 Hz, 1H; H21) 8.40 (dt, J = 8.1, 2.2 Hz, 1H; H19) 8.16 (d, J = 8.2 Hz, 2H; H9,11) 7.78 (d, J = 8.2 Hz, 2H; 8,12) 7.74 (d, J = 7.7 Hz, 2H; 3,5) 7.56 (dd, J = 8.0, 4.8 Hz, 1H; H20) 7.49 (t, J = 7.6 Hz, 2H; H2,6) 7.39 (t, J = 7.3 Hz, 1H; H1)

Table 2
^{13}C NMR spectral data of 2,4-diaryl-1,3-Selenazole

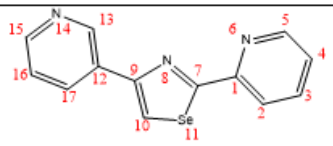
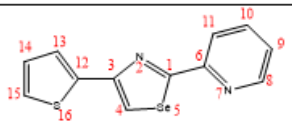
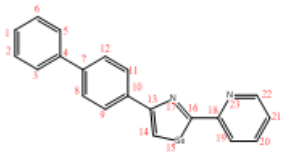
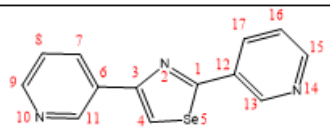
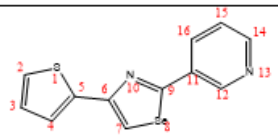
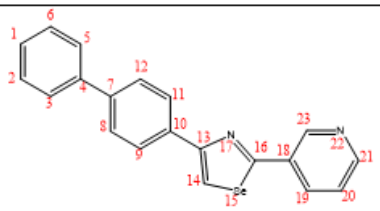
Comp.	Structure	Chemical shift (ppm)
1		176.86; C7, 154.49; C9, 152.94; C1, 149.73;C13, 148.83; C5,148.02; C15, 137.12; C17,133.77; C3, 131.33; C12,124.93; C2, 123.57; C16, 122.21;C4, 118.94; C10
2		176.25; C1, 152.31; C3, 151.65; C6, 150.57; C8, 139.41; C10,138.46;C12, 128.60; C15,126.41; C13 126.10; C14,124.81;C11, 121.46; C9, 118.77; C4
3		176.02; C16, 156.52; C13, 152.64; C18, 150.54; C22, 140.04; C10, 139.95; C7, 138.41; C20, 134.54; C4, 129.48; C2,6, 128.06; C1, 127.54; C8,12, 127.32; C9,11, 127.04; C3,5 126.01; C19, 123.47; C21, 118.90; C14
4		171.16; C1, 154.35; C3, 151.34; C13, 149.20; C11, 148.39; C15, 148.13; C9, 134.16; C17, 134.05; C7, 132.12; C12, 130.94; C6, 123.99; C16, 123.77; C8, 120.56; C4.
5		170.43; C9, 151.91; C6, 151.19; C12, 148.39; C14, 139.12; C5, 134.05; C16, 132.11; C11, 127.90; C15, 125.63; C4, 124.55; C2, 123.94; C3, 117.60; C7
6		170.25; C16, 155.50; C13, 151.19; C23 147.45; C21, 139.64; C10, 139.61; C7, 134.20; C4, 133.82; C19, 131.68; C18, 129.07; C2,6, 127.68; C1, 127.15; C8,12, 127.08; C9,11, 126.64; C3,5, 124.44; C20, 122.18; C14.

Table 3. Some of the calculated energy values (au) of 2,4-diaryl-1,3-Selenazole (1-6) molecules according to BLYP/3-21G calculation.

No.	HOMO	LUMO	ΔE	Total energy
1	-242.78.71	-237.75	4.96	-9749944.64
2	-216.43	-212.52	3.91	-1397613.12
3	-135.78	-133.34	2.44	-1398002.5
4	-138.63	-138.17	0.46	-1319282.70
5	-71.26	-67.54	3.72	-1709244.25
6	-313.56	-309.05	4.51	-718049.97

Table 4
Selected QSAR properties of the 2,4-diaryl-1,3-Selenazole (1-6) molecules calculated for the optimized structures

No	Surface area (approx.) (Å^2)	Surface area (grid) (Å^2)	Volume (Å^3)	Hydration energy (kcal/mol)	LogP	Refractivity (Å^3)	Polarizability (Å^3)
1	47.523	10.534	689.21	-5.66	86.1	35.16	04.62
2	65.023	417.28	669.50	-4.80	-0.09	65.19	26.63
3	426.79	546.44	913.07	-5.14	3.75	88.89	36.77
4	326.09	429.75	684.92	-6.29	1.75	61.87	26.40
5	320.89	410.75	663.83	-5.44	-0.02	65.53	26.63
6	427.13	543.42	909.24	-5.78	3.82	89.23	36.77

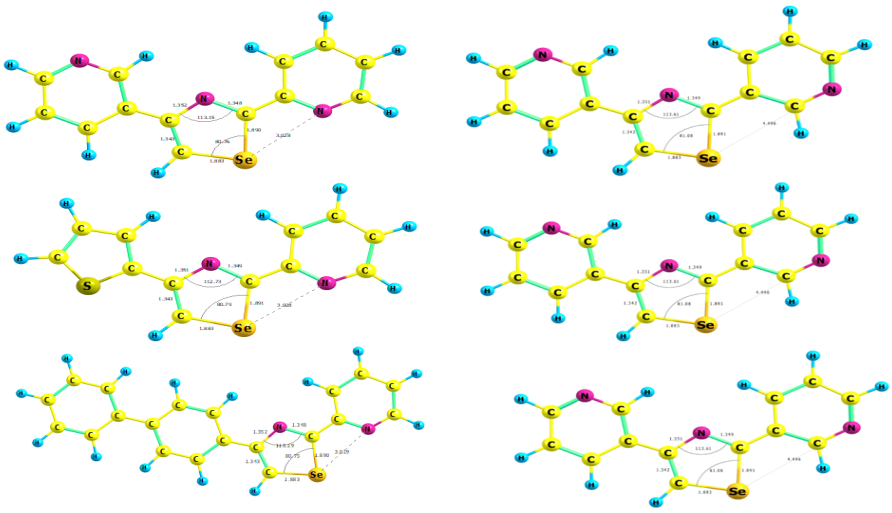


Fig. 1. Optimized structure of 2,4-diaryl-1,3-Selenazole (1-6) with selected geometrical parameters, where bond lengths are in angstroms (Å) and bond angles in degrees (∘).

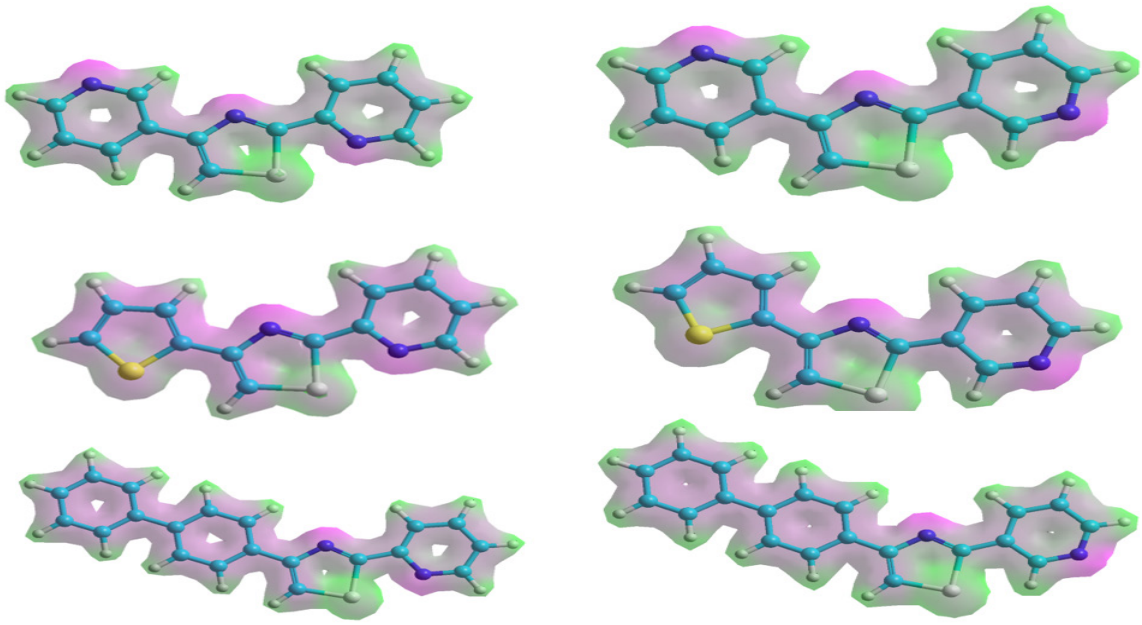


Fig. 2. Three-dimensional isosurface plots structure of 2,4-diaryl-1,3-Selenazole (1-6)