The synthesis and antimicrobial activity of 2-((4',5'-dihydrooxazol-2'-yl)methylsulfonyl)benzoxazole, 2-((4',5'-dihydrooxazol-2'-yl)methylsulfonyl)benzothiazole, 2-((4',5'-dihydrooxazol-2'-yl)methylsulfonyl)-1\(H\)-benzimidazole, 2-((4',5'-dihydrothiazol-2'-yl)methylsulfonyl)benzoxazole, 2-((4',5'-dihydrothiazol-2'-yl)methylsulfonyl)benzothiazole, 2-((4',5'-dihydrothiazol-2'-yl)methylsulfonyl)-1\(H\)-benzimidazole, 2-((4',5'-dihydro-1'H-imidazol-2'-yl)methylsulfonyl)benzoxazole, 2-((4',5'-dihydro-1'H-imidazol-2'-yl)methylsulfonyl)benzothiazole and 2-((4',5'-dihydro-1'H-imidazol-2'-yl)methylsulfonyl)-1\(H\)-benzimidazole were presented in this section.

The reactive intermediates benzoxazole-2-thiol (22), benzothiazole-2-thiol (23) and 1\(H\)-benzimidazole-2-thiol (24) used for the synthesis of above mentioned heterocycles were prepared by the treatment of 2-aminophenol / 2-aminothiophenol / 1,2-phenylenediamine with carbon disulfide in the presence of potassium hydroxide in ethanol (Scheme II.1).

\[
\text{SCHEME II.1}
\]

\[
\text{(i) } \text{CS}_2 / \text{KOH} / \text{EtOH} / \Delta \quad \text{X = O / S / NH}
\]

The reaction of compounds 22 / 23 / 24 with chloroacetic acid in the presence of sodium hydroxide in methanol resulted in 2-(benzoxazol-2-ythio)acetic acid (25), 2-(benzothiazol-2-ythio)acetic acid (26) and 2-(1\(H\)-benzimidazol-2-ythio)acetic acid (27). Oxidation of the latter compounds with hydrogen peroxide gave 2-(benzoxazol-2-ylsulfonyl)acetic acid (28), 2-(benzothiazol-2-ylsulfonyl)acetic acid (29) and 2-(1\(H\)-
benzimidazol-2-ylsulfonyl)acetic acid (30) (Scheme II.2 & Table II.1). In the IR spectra of 28, 29 and 30 the absorption bands observed in the regions 1140-1156 & 1349-1357, 1560-1582, 1688-1695 and 3415-3433 cm\(^{-1}\) were attributed to SO\(_2\), C=N, C=O and OH, respectively. The compound 30 showed another absorption band at 3226 cm\(^{-1}\) due to NH (Table II.2). The \(^1\)H NMR spectra of 28, 29 and 30 exhibited a sharp singlet at \(\delta\) 4.41, 4.54, 4.39 due to methylene protons present between carboxylic acid and sulfonyl group. Moreover, a broad singlet was observed at 10.46, 10.58, 10.43 ppm due to OH. The compound 30 presented another broad singlet at 11.30 ppm for NH of benzimidazole (Table II.3). The signals of NH and OH disappeared on deuteration. The \(^{13}\)C NMR spectra of 28, 29 and 30 displayed signals at \(\delta\) 60.5, 60.8, 60.1 (CH\(_2\)), 161.3, 164.3, 150.5 (C-2) and 169.6, 168.7, 170.2 ppm (CO\(_2\)H) (Table II.3).
The compounds 28, 29 and 30 on esterification with methanol in the presence of concentrated sulfuric acid produced methyl 2-(benzoxazol-2-ylsulfonyl)acetate (31), methyl 2-(benzothiazol-2-ylsulfonyl)acetate (32) and methyl 2-(1H-benzimidazol-2-yl-sulfonyl)acetate (33) (Scheme II.2 & Table II.1). The IR spectra of these compounds showed an absorption band at 1716, 1720, 1715 cm\(^{-1}\) for ester functionality besides the bands due to SO\(_2\) and C=N. Moreover, the compound 33 exhibited an absorption band at 3229 cm\(^{-1}\) for NH (Table II.2). The \(^1\)H NMR spectra of 31 (Fig. II.1), 32 and 33 presented two sharp singlets at \(\delta\) 3.81, 3.85, 3.78 and 4.45, 4.57, 4.43 which were attributed to methoxy protons of carbomethoxy group and methylene protons present between sulfonyl & carbomethoxy group. The compound 33 showed another broad singlet at 11.43 ppm due to NH of benzimidazole which disappeared on deuteration (Table II.3). The \(^13\)C NMR spectra of 31 (Fig. II.2), 32 and 33 displayed signals at \(\delta\) 52.7, 53.1, 52.5; 60.9, 61.1, 60.8; 154.7, 164.8, 147.7 and 165.0, 165.4, 164.8 ppm due to OCH\(_3\), CH\(_2\), C-2 and CO\(_2\)Me, respectively (Table II.3).

The reaction of compounds 31, 32 and 33 with 2-aminoethanol and \(n\)-butyllithium complexed with a suspension of 5-10\% molar equivalent of anhydrous samarium(III) chloride in toluene afforded 2-(((4',5'-dihydrooxazol-2'-yl)methylsulfonyl)benzoxazole (34), 2-(((4',5'-dihydrooxazol-2'-yl)methylsulfonyl)benzothiazole (35) and 2-(((4',5'-dihydrooxazol-2'-yl)methylsulfonyl)-1H-benzimidazole (36) (Scheme II.3 & Table II.1). The compounds 34, 35 and 36 in their IR spectra showed absorption bands in the regions 1145-1159 & 1355-1359 and 1575-1602 due to SO\(_2\) and C=N. Besides, compound 36 exhibited another absorption band at 3332 cm\(^{-1}\) due to NH (Table II.2). The \(^1\)H NMR spectra of 34 (Fig. II.3), 35 and 36 presented a singlet at \(\delta\) 4.47, 4.58, 4.38 due to methylene protons. In addition, two triplets were observed at 3.42, 3.46, 3.40 and 3.93, 3.95, 3.85 which were assigned to oxazoline ring protons, C\(_{4'}\)-H and C\(_{5'}\)-H. Besides, compound 36 displayed a broad singlet at 11.53 ppm due to NH of benzimidazole which disappeared when D\(_2\)O was added (Table II.3). The \(^13\)C NMR spectra of 34 (Fig. II.4), 35 and 36 showed signals at \(\delta\) 51.2, 52.6, 50.8 (C-4'), 61.3, 61.5, 61.1 (CH\(_2\)), 62.7, 62.9, 61.9 (C-5'), 162.3, 163.8, 153.9 (C-2) and 164.5, 165.1, 163.7 ppm (C-2') (Table II.3).

Similar cyclocondensation of compounds 31, 32 and 33 with 2-aminoethanethiol furnished 2-(((4',5'-dihydrothiazol-2'-yl)methylsulfonyl)benzoxazole (37), 2-(((4',5'-dihydrothiazol-2'-yl)methylsulfonyl)benzothiazole (38) and 2-(((4',5'-dihydrothiazol-2'-yl)methylsulfonyl)-1H-benzimidazole (39) (Scheme II.4, Table II.1).
dihydrothiazol-2'-yl)methylsulfonyl)benzothiazole (38) and 2-((4',5'-dihydrothiazol-2'-yl)methylsulfonyl)-1H-benzimidazole (39) (Scheme II.3 & Table II.1). The IR spectra of these compounds exhibited absorption bands at 1152-1160 & 1356-1360 (SO$_2$), 1580-1605 (C=N) and the compound 39 showed another band at 3340 cm$^{-1}$ (NH) (Table II.2).

The $^1$H NMR spectra of 37, 38 (Fig. II.5) and 39 displayed a singlet and two triplets at $\delta$ 4.48, 4.54, 4.45; 4.29, 4.22, 4.30 and 3.37, 3.34, 3.41 ppm which were attributed to methylene protons flanked between SO$_2$ & heterocyclic ring, C$_4$-H and C$_5$-H, respectively. In addition to these, a broad singlet at 11.61 ppm was observed in 39 due to NH which disappeared on deuteration (Table II.3). The $^{13}$C NMR spectra of 37 presented signals at $\delta$ 37.9, 61.6, 63.2, 163.7, 173.7, 38 (Fig. II.6) at 38.7, 61.9, 62.8, 165.4, 173.5 and 39 at 37.7, 61.4, 61.9, 154.2, 174.7 ppm due to C-5', CH$_2$, C-4', C-2, C-2', respectively (Table II.3).

![Scheme II.3](image_url)
Adopting similar methodology, 2-((4',5'-dihydro-1'H-imidazol-2'-yl)methylsulfonyl)benzoxazole (40), 2-((4',5'-dihydro-1'H-imidazol-2'-yl)methylsulfonyl)benzothiazole (41) and 2-((4',5'-dihydro-1'H-imidazol-2'-yl)methylsulfonyl)-1'H-benzimidazole (42) were prepared from 31 / 32 / 33 and 1,2-ethanediamine in the presence of n-butyllithium and samarium(III) chloride (Scheme II.3 & Table II.1). The IR spectra of 40, 41 and 42 exhibited absorption bands in the regions 1147-1163 & 1355-1363 (SO$_2$), 1585-1595 (C=N) and 3335-3343 cm$^{-1}$ (NH) (Table II.2). The $^1$H NMR spectra of 40, 41 and 42 (Fig. II.7) displayed a singlet at $\delta$ 4.53, 4.57, 4.39 due to methylene protons and another singlet at 3.45, 3.48, 3.42 due to imidazoline ring protons. Besides, a broad singlet was observed at 5.09 in 40, at 5.11 in 41 and at 5.12 in 42 due to NH of imidazole. Another broad singlet was appeared at 11.75 ppm in 42 due to NH of benzimidazole. The signals of NH disappeared when D$_2$O was added (Table II.3). The $^{13}$C NMR spectra of 40 showed signals at $\delta$ 52.8, 62.3, 158.5, 164.9; 41 at 53.1, 62.5, 159.6, 165.8 and 42 (Fig. II.8) at 51.9, 61.9, 158.9, 152.5 ppm which were assigned to C-4' & C-5', CH$_2$, C-2' and C-2, respectively (Table II.3). The HRMS mass spectrum of 40 (Fig. II.9) exhibited M+Na peak at m/z 288.2775 which is in agreement with the chemical composition C$_{11}$H$_{11}$N$_3$O$_3$S+Na.

The 70 eV mass spectrum of 42 (Fig. II.10) displayed a low intense M$^+$ peak at m/z 264 corresponding to the molecular formula C$_{11}$H$_{12}$N$_4$O$_2$S. Disintegration $\alpha$ to SO$_2$ of the M$^+$ produced 1H-benzimidazol-2-ylsulfonyl (m/z 181), 4,5-dihydroimidazol-2-ylmethysulfonyl (m/z 147), 4,5-dihydro-2-methyl-1H-imidazolyl (m/z 83) cations. On the other hand cleavage of benzimidazole ring led to the appearance of phenylisocyanide radical cation (m/z 103). The ion at m/z 181 appears as the high abundant ion of the spectrum.
SCHEME II.4