

SYNTHESIS AND INVESTIGATION OF MASS SPECTRA OF SOME NOVEL BENZIMIDAZOLE DERIVATIVES

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2-Substituted benzimidazoles (**3**) and (**4a-c**) were prepared via condensation of ethyl 2-thionyl-pyruvate (**1**) and hydrazidoyl derivatives (**2a-c**) with *o*-phenylene diamine in acetic acid. Acetylation of compound (**4a**) with acetic anhydride yielded the corresponding *N*-acetyl derivative (**5**). Treatment of compound **4b** with hydrazine hydrate gave the corresponding hydrazino derivative (**6**). Reaction of 2-[(2-thionyl)acetyl] benzimidazole (**3**) with hydrazine hydrate gave the pyrazolyl derivative (**7**) and hydrazino derivative (**8**). Alkylation of compound **3** with alkyl halide gave the corresponding 2,3-disubstituted benzimidazoles (**9a, b**). Pyrrolo[1,2-*a*] benzimidazole derivatives **10** and **11** were prepared via cyclocondensation of compound **3** with acetic anhydride in presence of AcONa and phosphorus oxychloride.

The electron impact mass spectra of both of the above series of compounds have also been recorded and their fragmentation patterns are discussed.

Key words: mass spectrum; synthesis; and benzimidazoles

СИНТЕЗА И ИСТРАЖУВАЊЕ НА МАСЕНИТЕ СПЕКТРИ НА НЕКОИ НОВИ БЕНЗИМИДАЗОЛНИ ДЕРИВАТИ

Приготвени се 2-супституирани бензимидазоли (**3**) и (**4a-c**) со кондензација на етил-2-тионилпируват (**1**) и на деривати на хидразидоил **2a-c** со *o*-фенилен диамин во оцетна киселина. При ацетирање на **4a** со анхидрид на оцетна киселина се добива соодветниот дериват на *N*-ацетил (**5**). Обработката на **4b** со хидразинхидрат го дава соодветниот хиразинодериват (**6**). Реакцијата на 2-[(2-тионил)ацетил]бензимидазол (**3**) со хидразинхидрат ги дава дериватот на пирозолил (**7**) и хидразинодериватот (**8**). При алкилирање на **3** со алкилхалид се добиваат соодветните 2,3-дисупституирани бензимидазоли (**9a, b**). Дериватите на пироло[1,2-*a*]бензимидазол **10** и **11** беа подготвени со циклокондензација на **3** со анхидрид на оцетна килсеина во присуство на AcONa и фосфороксихлорид.

Снимени се електронските масени спектри на двете наведени серии соединенија и дискутирани се нивните масени фрагментации.

Клучни зборови: масени спектри; синтеза; бензимидазоли

INTRODUCTION

The benzimidazole ring is an important pharmacophore in modern drug discovery [1]. Benzimidazole derivatives exhibit significant activity against several viruses such as HIV [2,3], herpes (HSV-1) [4], RNA [5] and influenza [6].

Benzimidazoles are very important intermediates in organic reactions [7], therefore the preparation of benzimidazoles have gained considerable attention in recent years [8–10].

In a previous work, Mohy El-Deen *et al* [11, 12] reported the synthesis of 2-substituted quinoxaline from ethyl 2-thionylpyruvate (**1**) with *o*-

phenylene diamine in 4N hydrochloric acid with ring cyclization with the removal of ethanol and water. This paper describes the synthesis of 2-substituted benzimidazoles from condensation of ethyl 2-thionyl pyruvate and their derivatives (**1**) and (**2a-c**) with *o*-phenylene diamine in acetic acid. The electron impact (EI) ionization mass spectral fragmentation of the prepared compounds is also described.

EXPERIMENTAL

The melting points were determined in capillaries with a MEL-TEMP II Laboratory Devices, USA, and are uncorrected. Infrared spectra were recorded on Perkin-Elmer 337 Spectrophotometer using KBr wafers. Proton NMR spectra were obtained on a Varian EM 360 spectrometer using solution in hexadeuteriodimethyl sulfoxide with tetramethylsilane as the internal standard. Mass spectra were recorded on a VG Autospec GEIFAB⁺ and a Hewlett Packard MS-Engine thermospray and ionization by electron impact at 70 eV. The accelerating voltage was 6 kV, the temperature of the source was ~200 °C, and the emission current ~100 mA. Micro-analysis was conducted using a Perkin-Elmer 2408 CHN analyzer.

Ethyl-2-thionylpyruvate (1)

A mixture of 2-acetylthiophene (0.01 mol) and diethyl oxalate (0.01 mol) in 50 mL sodium methoxide solution (0.005 g Na /25 mL methanol) was warmed for 20 min, and then cooled. The solid that separated was washed with dilute hydrochloric acid and recrystallized from ethanol to give **1** as yellow crystals, m.p. 95 °C, yield 82 %, ν_{\max} (KBr) 1745 cm⁻¹ (CO of ester), 1643 cm⁻¹ (CO of β -diketone). δ_{H} (CDCl₃): 1.30 (t, 3H, CH₃), 3.31 (s, 2H, COCH₂CO), 4.23 (q, 2H, OCH₂) and 6.32–7.50 (m, 3H, thiophene ring) ppm.

Anal. C₁₀H₁₀O₄S (226)

Calcd: C 53.01; H 4.42; S 14.16 %

Found: C 52.89; H 4.24; S 14.00 %

Ethyl- β -(2-thionyl)- β -arylhydrazino pyruvate (2a-c)

A solution of (**1**) (0.01 mol) in ethanol (50 mL) was stirred with sodium acetate (3g) and the mixture chilled in ice to 0–5 °C. A cold aqueous

solution (0–5 °C) of the diazonium salt (0.01 mol) was added dropwise with stirring for 45 min. After addition the mixture was stirred for a further 30 min and then left for 2 h in a refrigerator. The precipitated products were collected, washed with water and recrystallized from ethanol to yield **2a-c**.

Ethyl- β -(2-thionyl)- β -phenyl hydrazino pyruvate (2a), yield 68 %, mp. 130 °C, ν_{\max} (KBr): 1739 cm⁻¹ (CO of ester), 1635 cm⁻¹ (CO of β -diketone), 3401 cm⁻¹ (NH). δ_{H} (CDCl₃): 1.11 (t, 3H, CH₃), 3.58 (q, 2H, OCH₂), 7.24–8.10 (m, 8H, ArH and thiophene ring) and 11.10 (s, 1H, NH) ppm.

Anal. C₁₆H₁₄N₂O₄S (330)

Calcd: C 58.18; H 4.24; N 8.48; S 9.69 %

Found: C 58.02; H 4.07; N 8.22; S 9.36 %

Ethyl- β -(2-thionyl)- β -(3-methylphenyl)hydrazino pyruvate (2b), yield 71 %, mp. 137 °C, ν_{\max} (KBr): 1732 cm⁻¹ (CO of ester), 1632 cm⁻¹ (CO of β -diketone), 3407 (NH) cm⁻¹. δ_{H} (CDCl₃): 1.20 (t, 3H, CH₃), 2.32 (s, 3H, CH₃), 3.58 (q, 2H, OCH₂), 6.81–7.98 (m, 7H, ArH and thiophene ring) and 11.10 (s, 1H, NH) ppm.

Anal. C₁₇H₁₆N₂O₄S (344)

Calcd: C 59.30; H 4.65; N 8.14; S 9.30 %

Found: C 59.04; H 4.42; N 7.97; S 9.12 %

Ethyl- β -(2-thionyl)- β -(2-chlorophenyl) hydrazino pyruvate (2c), yield 72 %, m.p. 139 °C, ν_{\max} (KBr): 1738 cm⁻¹ (CO of ester), 1635 cm⁻¹ (CO of β -diketone), 3395 cm⁻¹ (NH), δ_{H} (CDCl₃): 1.11 (t, 3H, CH₃), 3.58 (q, 2H, OCH₂), 7.24–8.10 (m, 7H, ArH and thiophene ring) and 11.10 (s, 1H, NH) ppm.

Anal. C₁₆H₁₃N₂ClO₄S (364)

Calcd: C 52.73; H 3.57; N 7.69; Cl 9.62; S 8.79 %

Found: C 52.49; H 3.42; N 7.37; Cl 9.41; S 8.51 %

2-(Substituted) acetylbenzimidazoles (3 and 4a-c)

A mixture of **1** or **2a-c** (0.01 mol) with *o*-phenylene diamine (0.01 mol) in acetic acid (5 mL) was heated under reflux for 1 h. The product obtained after cooling was collected by filtration, washed with ethanol, dried and purified by recrystallization with acetic acid to give **3** and **4a-c**.

2-[(2-thionyl)acetyl]benzimidazole (3), as yellow crystals, yield 67 %, m.p. 271 °C, ν_{\max}

(KBr): 3164 cm^{-1} (NH), 1680 cm^{-1} (CO of β -diketone), 1620 cm^{-1} (C=N), 1603, 1582 cm^{-1} (C=C). δ_{H} (DMSO- d_6): 3.37 (s, 2H, COCH₂CO), 6.7–7.98 (m, 7H, ArH and thiophene ring) and 12.06 (s, 1H, NH) ppm.

Anal. C₁₄H₁₀N₂O₂S (270)

Calcd: C 62.22; H 3.70; N 10.37; S 11.85 %

Found: C 62.01; H 3.48; N 10.02; S 11.61 %

2-[(β -2-thionyl)- β -(phenyl)hydrazino] acetylbenzimidazole (**4a**) as orange crystals, yield 69 %, m.p. 240 °C. ν_{max} (KBr): 3229, 3187 cm^{-1} (NH), 1675 cm^{-1} (CO of β -diketone), 1628 cm^{-1} (C=N), 1605, 1588 cm^{-1} (C=C). δ_{H} (DMSO- d_6): 6.88–7.94 (m, 12H, ArH and thiophene ring), 11.03 (s, 1H, NNH) and 12.67 (s, 1H, NH) ppm.

Anal. C₂₀H₁₄N₄O₂S (374)

Calcd: C 64.17; H 3.74; N 14.97; S 8.55 %

Found: C 63.98; H 3.52; N 14.69; S 8.27 %

2-[(β -(2-thionyl)- β -(3-methylphenyl)hydrazino]-acetylbenzimidazole (**4b**) as orange crystals, yield 65 %, m.p. 160 °C. ν_{max} (KBr): 3220, 3185 cm^{-1} (NH), 1672 (CO of β -diketone), 1623 (C=N), 1606, 1591 cm^{-1} (C=C). δ_{H} (DMSO- d_6): 2.32 (s, 3H, CH₃), 6.88–7.94 (m, 11H, ArH and thiophene ring), 11.037 (s, 1H, NNH) and 12.6 (s, 1H, NH) ppm.

Anal. C₂₁H₁₆N₄O₂S (388)

Calcd: C 64.95; H 4.12; N 14.43; S 8.25 %

Found: C 64.67; H 4.01; N 14.20; S 8.02 %

2-[(β -(2-thionyl)- β -(2-chlorophenyl)hydrazino]-acetylbenzimidazole (**4c**) as red crystals, yield 66 %, m.p. 182 °C. ν_{max} (KBr): 3227, 3183 cm^{-1} (NH), 1672 cm^{-1} (CO of β -diketone), 1623 cm^{-1} (C=N), 1603, 1589 cm^{-1} (C=C). δ_{H} (DMSO- d_6): 6.96–7.7 (m, 11H, ArH and thiophene ring), 11.10 (s, 1H, NH) and 12.6 (s, 1H, NH) ppm.

Anal. C₂₀H₁₃N₄ClO₂S (405.5)

Calcd: C 58.82; H 3.19; N 13.73; Cl 8.58; S 7.84 %

Found: C 58.52; H 3.03; N 13.42; Cl 8.29; S 7.61 %

3-Acetyl-2-[(β -(2-thionyl)- β -(phenylhydrazino)]-acetylbenzimidazole (**5**)

A solution of **4a** (0.01 mol) in acetic anhydride (30 mL) was heated under reflux for 3 h. The product formed after being cooled was filtered off,

dried and purified by recrystallization with ethanol to give **5** as yellow crystals, yield 63 %, m.p. 145 °C. ν_{max} (KBr): 3185 cm^{-1} (NH), 1685, 1665 cm^{-1} (CO of β -diketone and acetyl), 1628 cm^{-1} (C=N), 1603, 1589 cm^{-1} (C=C). δ_{H} (DMSO- d_6): 2.32 (s, 3H, CH₃CO), 6.88–7.94 (m, 12H, ArH and thiophene ring) and 11.03 (s, 1H, NH) ppm.

Anal. C₂₂H₁₆N₄O₃S (416)

Calcd: C 63.46; H 3.85; N 13.46; S 7.69 %

Found: C 63.16; H 3.62; N 13.21; S 7.46 %

Reaction of **4b** with hydrazine hydrate, formation of (**6**)

A mixture of **4b** (0.01 mol) and hydrazine hydrate (0.02 mol) was fused on a hot plate for 2–3 min, after which dimethyl formamide was added (30 mL). The mixture was heated under reflux for 2–3 h, and then cooled and poured into water. The solid formed was filtered off, washed with water, dried, and recrystallized from ethanol to give **6** as yellow crystals, yield 63 %, m.p. 160 °C. ν_{max} (KBr): 3402, 3122 cm^{-1} (NH₂), 3281 cm^{-1} (NH), 1631 cm^{-1} (C=N), 1607, 1591 cm^{-1} (C=C). Mass spectrum, m/z (%): 416 (M⁺, 7.10) 415 (M⁺–1, 13.80), 257 (6.90), 256 (9.50), 196 (3.70), 195 (7.90) 185 (5.00), 176 (1.30), 162 (22.00), 161 (19.30), 160 (96.60), 159 (6.30), 149 (9.50), 143 (5.60), 139 (11.90), 133 (6.30), 132 (100), 131 (73.00), 122 (5.00), 120 (4.50), 117 (2.90), 116 (3.20), 111 (6.60), 105 (6.30), 104 (6.90), 103 (5.00), 102 (5.30), 92 (6.90), 91 (5.00), 90 (11.40) 85 (4.80), 83 (3.20), 77 (7.10), 76 (12.40), 66 (20.10), 65 (18.80), 64 (51.60), 63 (31.50), 62 (11.10), 52 (16.90).

Anal. C₂₁H₂₀N₈S (416)

Calcd: C 60.58; H 4.81; N 26.92; S 7.69 %

Found: C 60.31; H 4.52; N 26.66; S 7.39 %

2-[5-(2-thionyl)pyrazol-3-yl]benzimidazole (**7**) 2-[(β -(2-thionyl)- β -(hydrazinovinyl) carbonyl]benzimidazole (**8**)

A mixture of **3** (0.01 mol) and hydrazine hydrate (0.01 mol) in dimethyl formamide was heated under reflux for 2–3 h. The reaction mixture was cooled and poured into water. The product formed was collected by filtration, washed with water, dried and dissolved in hot ethanol. The insoluble solid in hot ethanol was filtered off and

purified by recrystallization with xylene to give **8**. The filtrate was cooled and the solid formed was filtered off, dried and purified by recrystallization with ethanol to give **7**, pale yellow crystals, yield 43 %, m.p. 180 °C. ν_{\max} (KBr): 3225 cm^{-1} (NH), 1630 cm^{-1} (C=N), 1606, 1589 cm^{-1} (C=C). Mass spectrum, m/z (%): 267 (M^+ , 33.80) 183 (5.80), 182 (37.20), 131 (28.80), 122 (17.30), 118 (17.50), 111 (30.00), 109 (38.80), 108 (77.90), 107 (22.50), 98 (22.50), 97 (26.30), 92 (27.50), 91 (33.80), 90 (52.50), 84 (38.80), 83 (35.00), 78 (43.80), 77 (78.80), 76 (40.60), 74 (17.50), 67 (36.20), 66 (32.20), 65 (92.50), 64 (56.30), 63 (72.50), 53 (66.30), 52 (100), 51 (78.80), 50 (73.80).

Anal. $\text{C}_{14}\text{H}_{10}\text{N}_4\text{S}$ (267)

Calcd: C 62.92; H 3.75; N 20.97; S 11.98 %

Found: C 62.71; H 3.43; N 20.69; S 11.59 %

Compound (**8**) as yellow crystal, yield 33 %, m.p. 205 °C. ν_{\max} (KBr): 3343, 3105 (NH_2), 3253 cm^{-1} (NH), 1665 cm^{-1} (C=O), 1625 cm^{-1} (C=N), 1604, 1595 cm^{-1} (C=C). Mass spectrum, m/z (%): 285 (M^++1 , 7.60), 284 (M^+ , 39.20), 256 (22.80), 226 (3.80), 225 (22.80), 132 (17.70), 131 (29.10), 121 (29.10), 119 (25.30), 111 (19.00), 109 (30.60), 108 (100), 107 (17.70), 104 (24.10), 103 (26.60), 92 (39.20), 91 (27.80), 90 (15.20), 84 (32.40), 83 (15.20), 78 (39.20), 77 (25.80), 76 (29.10), 69 (45.60), 65 (24.10), 64 (34.20), 63 (29.10), 51 (30.40), 50 (43.00).

Anal. $\text{C}_{14}\text{H}_{12}\text{N}_4\text{OS}$ (284)

Calcd: C 59.15; H 4.23; N 19.72; S 11.27 %

Found: C 58.87; H 4.00; N 19.49; S 11.03 %

3-Substituted-2-[6-(thionyl)acetyl]benzimidazoles (**9a, b**)

A mixture of **3** (0.01 mol) and alkyl halides (such as benzyl chloride and phenacyl bromide) (0.01 mol) in dimethyl formamide (30 mL) were heated under reflux for 4 h. The reaction mixture was cooled and poured into water. The product formed was collected by filtration, washed with water, dried and purified by recrystallization with ethanol to give **9**.

3-Benzyl-2-[(2-thionyl)acetyl]benzimidazole (9a) as yellow crystals, yield 61 %, m.p. 197 °C. ν_{\max} (KBr): 1675 cm^{-1} (CO of β -diketone), 1624 cm^{-1} (C=N), 1605, 1589 cm^{-1} (C=C). δ_{H} (DMSO- d_6): 3.428 (s, 2H, COCH_2CO), 5.93 (s, 2H, CH_2), and 6.7–7.98 (m, 12H, ArH and thiophene ring) ppm.

Anal. $\text{C}_{21}\text{H}_{16}\text{N}_2\text{O}_2\text{S}$ (360)

Calcd: C 69.81; H 4.43; N 7.75; S 8.86 %

Found: C 69.63; H 4.22; N 7.51; S 8.48 %

3-Benzylmethyl-2-[(2-thionyl)acetyl]benzimidazole (9b) as yellow crystals, yield 68 %, m.p. 240 °C, ν_{\max} (KBr): 1688 cm^{-1} (CO of ketone), 1671 cm^{-1} (CO of β -diketone) 1627 cm^{-1} (C=N), 1605, 1591 cm^{-1} (C=C). δ_{H} (DMSO- d_6): 3.428 (s, 2H, COCH_2CO), 6.22 (s, 2H, CH_2), and 6.7–7.98 (m, 12H, ArH and thiophene ring) ppm.

Anal. $\text{C}_{22}\text{H}_{16}\text{N}_2\text{O}_3\text{S}$ (388)

Calcd: C 68.04; H 4.12; N 7.22; S 8.25 %

Found: C 67.88; H 4.00; N 6.98; S 8.01 %

2-Methyl-3-(2-thionyl)-4H-4-oxo-pyrrolo[1,2-a]benzimidazole (**10**)

A mixture of **3** (0.01 mol) and fused sodium acetate (0.02 mol) in acetic anhydride (30 mL) was heated under reflux for 4 h. The reaction mixture was cooled and poured into water. The solid formed was collected by filtration, washed with water, dried and purified by recrystallization with acetic acid to give **10** as yellow crystals, m.p. 260 °C. ν_{\max} (KBr): 1685, 1668 cm^{-1} (CO), 1625 cm^{-1} (C=N), 1603, 1591 cm^{-1} (C=C). δ_{H} (DMSO- d_6): 2.556 (s, 3H, CH_3), and 6.7–7.98 (m, 7H, ArH and thiophene ring) ppm.

Anal. $\text{C}_{16}\text{H}_{10}\text{N}_2\text{O}_2\text{S}$ (294)

Calcd: C 65.31; H 3.40; N 9.52; S 10.88 %

Found: C 65.00; H 3.13; N 9.25; S 10.63 %

5-(2-thinyl)-3H-3-oxo-pyrrolo [1,2-a] benzimidazole (**11**)

A solution of (**3**) (0.01 mol) in phosphorus oxychloride (30 mL) was heated on a water bath for 3–4 h. The reaction mixture was cooled and poured into water. The product obtained was filtered off, washed with water, dried and recrystallized from ethanol to give **11** as pale yellow crystals, yield 58 %, m.p. 190 °C. ν_{\max} (KBr): 1672 cm^{-1} (C=O), 1627 cm^{-1} (C=N), 1605, 1595 cm^{-1} (C=C). δ_{H} (DMSO- d_6): 6.7–7.98 (m, 8H, ArH, pyrrolo and thiophene ring) ppm.

Anal. $\text{C}_{14}\text{H}_8\text{N}_2\text{OS}$ (252)

Calcd: C 66.66; H 3.17; N 11.11; S 12.70 %

Found: C 66.36; H 3.02; N 10.98; S 12.42 %

RESULTS AND DISCUSSION

Chemistry

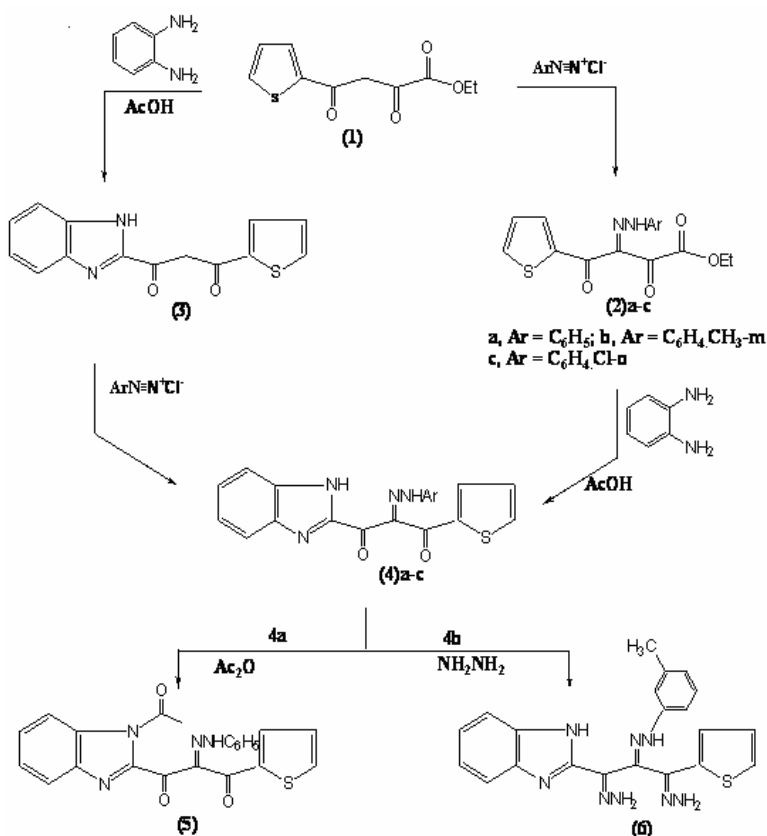
Ethyl 2-thionyl pyruvate (**1**) was prepared from 2-acetyl thiophene and diethyl oxalate in the presence of methoxide according to a published literature procedure [13].

The hydrazidoyl derivatives (**2a-c**) were prepared by coupling of (**1**) with diazotized amines, namely aniline, *m*-toluidine and *o*-chloroaniline in ethanolic solution buffered with sodium acetate [14, 15].

Condensation of **1** and **2a-c** with *o*-phenylene diamine in glacial acetic acid under reflux, gave the corresponding 2-[(2-thionyl)acetyl] benzimidazole (**3**) and 1-(1H-benzoimidazol-2-yl)-2-(2-(substituted phenyl) hydrazono)-3-(thiophen-2-yl) propan-1,3-dione (**4a-c**), respectively.

1-(1-acetyl-benzoimidazol-2-yl)-2-(2-phenylhydrazono)-3-(thiophen-2-yl)propan-1,3-dione (**5**) was prepared by acetylation of **4a** with acetic anhydride. The reaction of **4b** with hydrazine hydrate in dimethyl formamide under reflux gave the corresponding hydrazino derivatives (**6**) (Scheme 1).

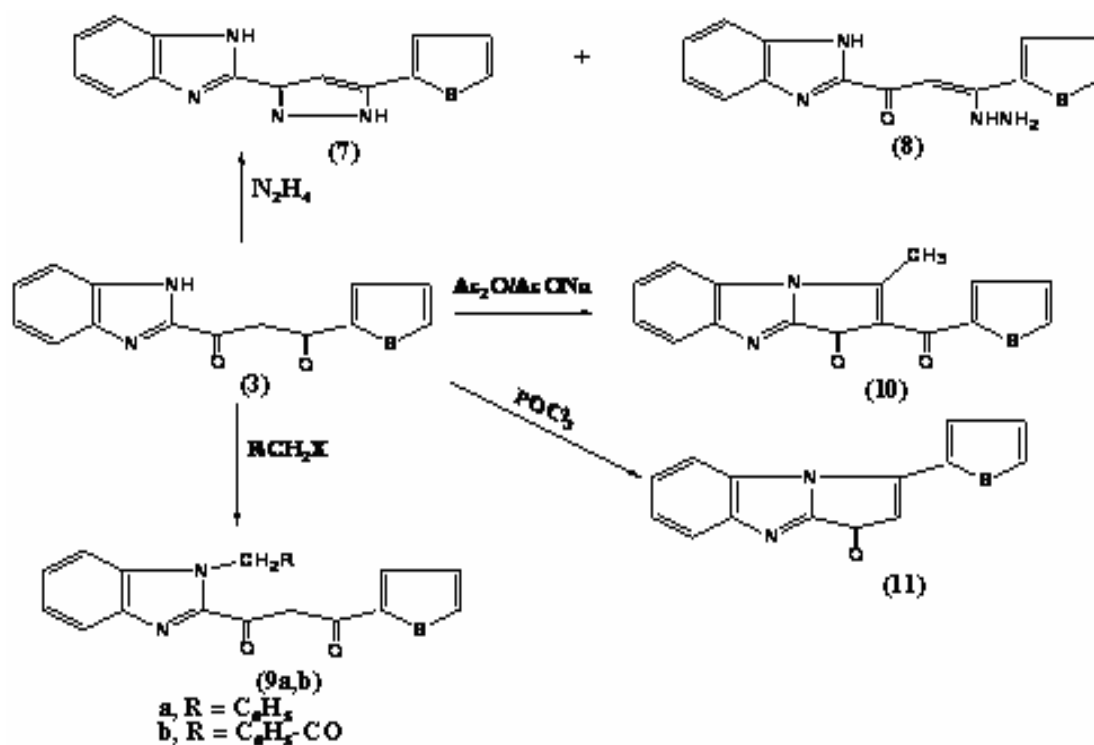
Condensation of 2-[(2-thionyl acetyl] benzimidazole (**3**) with hydrazine hydrate in dimethyl formamide yielded the corresponding 2-(5-thionyl-pyrazol-3-yl)benzimidazole (**7**) and 2-[(β -2-thionyl- β -hydrazino) vinyl] carbonyl-benzimidazole (**8**). Treatment of compound **3** with alkyl halides such as benzyl chloride and phenacyl bromide in dimethyl formamide under reflux, yielded the corresponding 3-substituted-2-[(2-thionyl)acetyl]benzimidazoles (**9a, 9b**)



Scheme 1

2-Methyl-3-(2-thionyl)-4*H*-4-oxopyrrolo[1,2-*a*]-benzimidazole (**10**) was prepared by the cyclocondensation of 2-[(2-thionyl)acetyl]benzimidazole (**3**) with acetic anhydride in the presence of fused sodium acetate under reflux.

2-[(2-thionyl)acetyl]benzimidazole (**3**) reacted with phosphorus oxychlorid under reflux on a water bath affording 2-(2-thionyl)-4*H*-4-oxopyrrolo[1,2-*a*]benzimidazole (**11**) (Scheme 2).



Scheme 2

Mass spectroscopy

The mass spectral decomposition modes of various benzimidazole derivatives containing thiophene substituents have been suggested and investigated.

Compounds 2, 4 and 5

Table 1 lists the m/z (relative abundance, %) values of the principal fragments of the synthesized compounds 2, 4 and 5.

The mass spectra of compounds 2, 4 and 5 show relatively strong molecular ions and peaks typical of a cleavage and rearrangement processes type fragmentation. Thus, compounds 2a-c showed an intense molecular ion peak at 330, 344 and 364 corresponding to the molecular formulas $\text{C}_{16}\text{H}_{14}\text{N}_2\text{O}_4\text{S}$, $\text{C}_{17}\text{H}_{16}\text{N}_2\text{O}_4\text{S}$ and $\text{C}_{16}\text{H}_{13}\text{N}_2\text{ClO}_4\text{S}$, respectively. From a study of the mass spectra of compounds 2a-c, it was found that the molecular ion for all these compounds fragmented further and involved two various possible pathways as illustrated by Scheme 3 showing representative examples.

However, the molecule of m/z 344 (Fig. 1) fragmented via the pathway A to give the ion of m/z 298, which fragmented further to give ion of m/z 270 by losing CO. The ion of m/z 270 was broken to give the ion m/z 242 by losing CO. The ion of

m/z 242 underwent loss of $\text{C}_8\text{H}_7\text{N}_2$ to give a stable peak at m/z 111, which fragmented further to give a peak at m/z 83 by losing CO.

Subsequently, the molecular ion m/z 344 fragmented via the pathway B to give a fragmented ion of m/z 300 by losing ethylene epoxide. Ion m/z 300 fragmented to give an ion of m/z 271, which lost CO to give a fragmented of m/z 243. This fragmented led to m/z 106, 91 and m/z 65, respectively.

The mass spectra of compounds 4a, 4b and 4c showed intense molecular ion peaks at m/z 374, 388 and 408, consistent with the molecular formulas $\text{C}_{20}\text{H}_{14}\text{N}_4\text{O}_2\text{S}$, $\text{C}_{21}\text{H}_{16}\text{N}_4\text{O}_2\text{S}$ and $\text{C}_{20}\text{H}_{13}\text{N}_4\text{ClO}_2\text{S}$, respectively.

The molecular ion of compound 4a (Fig. 2) fragmented further and involved two possible pathways as illustrated in Scheme 4 as representative example.

The molecular ion of m/z 374 fragmented via the pathway A to give stable ion of m/z 111 by losing 1-phenylamino-4-oxopyrazolo[1,2-a]benzimidazole radical. The stable ion of m/z 111 was broken to give the m/z 83 by losing CO group.

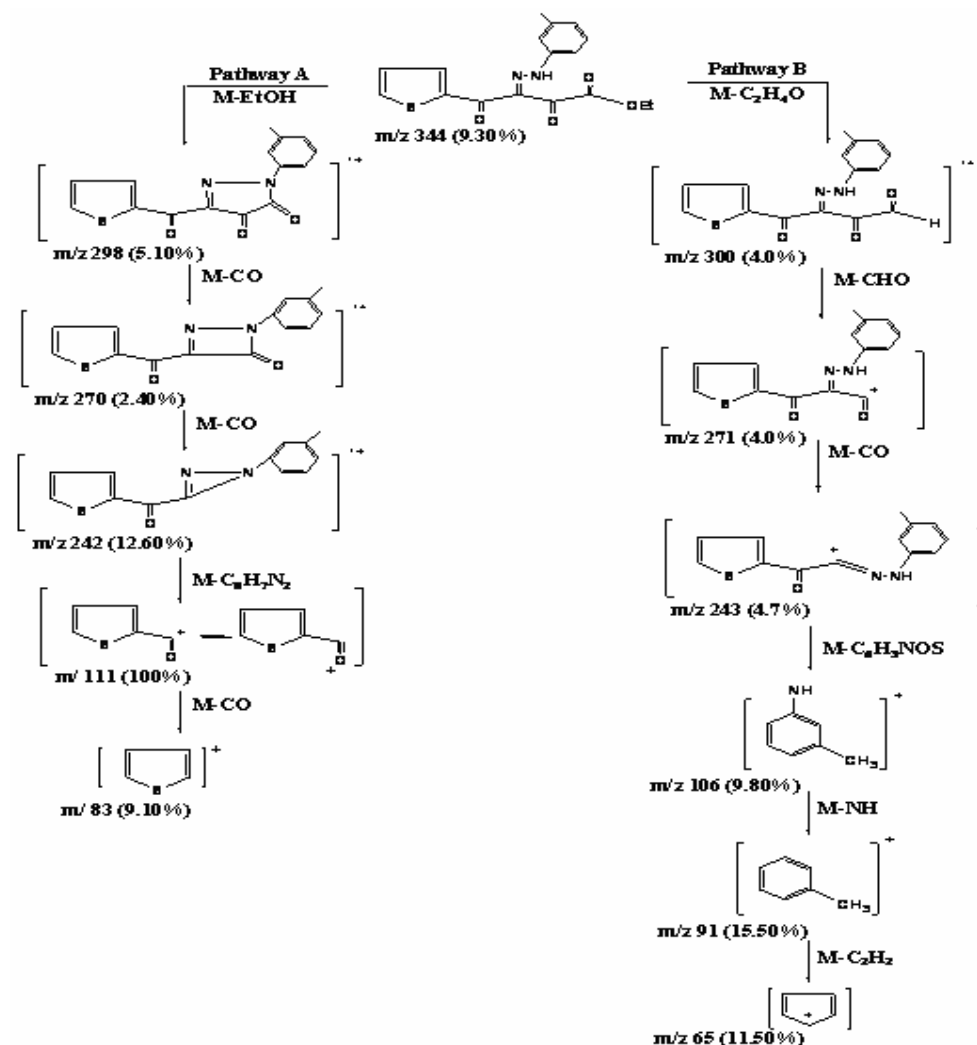
Accordingly, the same ion of m/z 374 fragmented via the pathway B by losing thionyl radical to give an ion m/z 263, which lost carbon monoxide to give an ion of m/z 235. This fragmentation led to ion of m/z 119, 92 and m/z 77, respectively.

Table 1

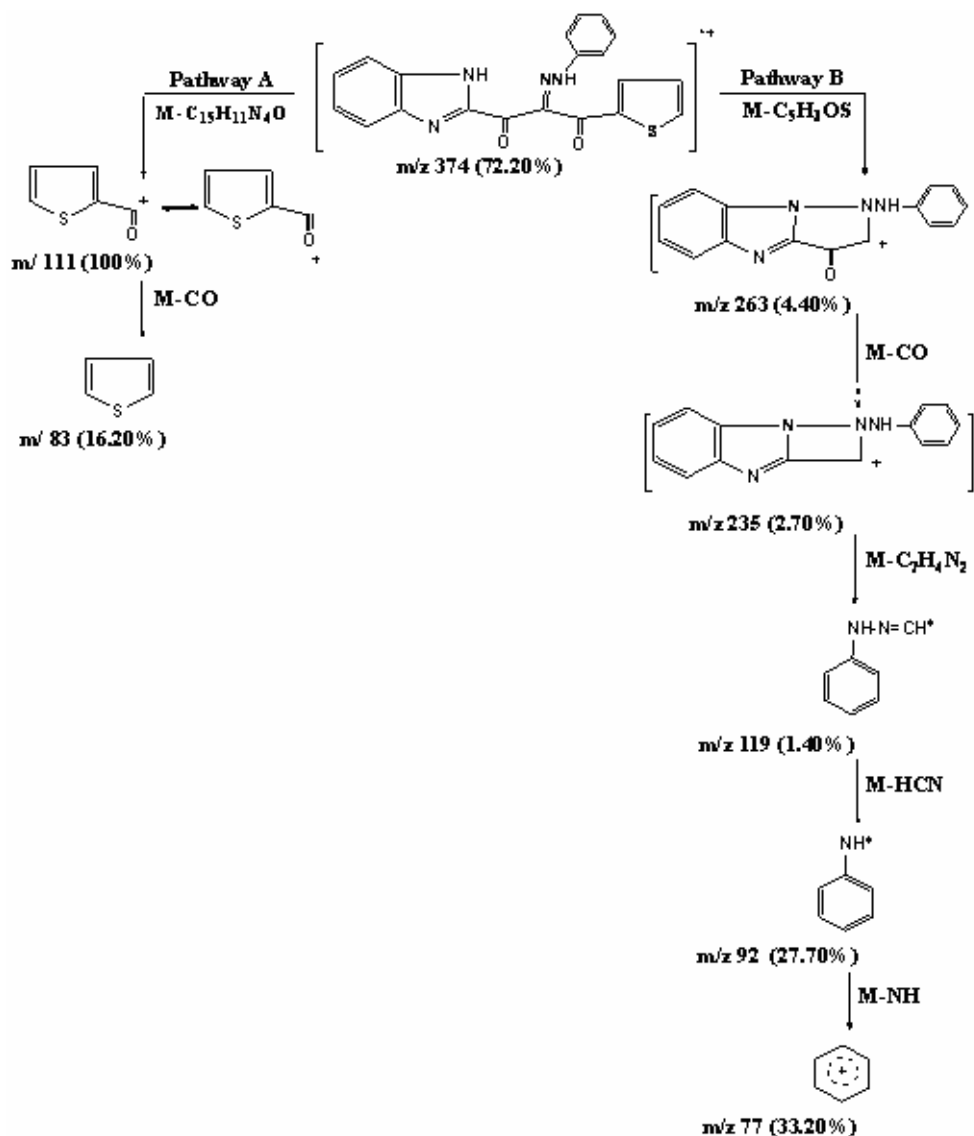
EI Spectra (70 eV) of compounds 2, 4 and 5

No.	M ⁺	Pathway A		Pathway B		Other ions
		M-	m/z	M-	m/z	
2a	[C ₁₆ H ₁₄ N ₂ O ₄ S] ⁺ 330 (15.00)	C ₂ H ₅ OH	[C ₁₄ H ₈ N ₂ O ₃ S] ⁺ 284 (7.10)	C ₂ H ₄ O	[C ₁₄ H ₁₀ N ₂ O ₃ S] ⁺ 286 (6.30)	331(M ⁺ +1,5.2), 296(1.2), 287(3.2), 285(4.1), 283(2.1), 258(2.2), 255(3.9), 227(1.6), 226(2.1), 213 (1.6), 212(2.2), 117(1.3), 116(2.1), 112(17.2), 110(22.1), 91(11.2), 90(8.9), 84(2.2), 82(6.3), 77(22), 76(11.3), 75(2.5), 65(11.2), 64(9.2), 51(12.7)
		CO	[C ₁₃ H ₈ N ₂ O ₂ S] ⁺ 256 (15.30)	CHO	[C ₁₃ H ₉ N ₂ O ₂ S] ⁺ 257 (8.35)	
		CO	[C ₁₂ H ₈ N ₂ OS] ⁺ 228 (8.30)	CO	[C ₁₂ H ₉ N ₂ OS] ⁺ 229 (6.35)	
		C ₇ H ₅ N ₂	[C ₅ H ₃ OS] ⁺ 111 (100)	C ₆ H ₃ NOS	[C ₆ H ₆ N] ⁺ 92 (22.30)	
		CO	[C ₄ H ₃ S] ⁺ 83 (19.10)	NH	[C ₆ H ₅] ⁺ 77 (36.70)	
2b	[C ₁₇ H ₁₆ N ₂ O ₄ S] ⁺ 344 (9.30)	C ₂ H ₅ OH	[C ₁₅ H ₁₀ N ₂ O ₃ S] ⁺ 298 (5.10)	C ₂ H ₄ O	[C ₁₅ H ₁₂ N ₂ O ₃ S] ⁺ 300 (4.00)	330(4.3), 299(2.3), 297(4.7), 244 (2.8), 189(1.4), 188(2.8), 159(2.0), 153(1.5), 133(5.0), 132(3.4), 119(3.9), 112(7.5), 110(3.1), 107 (2.5), 104(6.6), 90(2.2), 82(2.0), 77(16.8), 65(11.5), 64(3.1), 52(6.1), 51(8.6)
		CO	[C ₁₄ H ₁₀ N ₂ O ₂ S] ⁺ 270 (2.40)	CHO	[C ₁₄ H ₁₁ N ₂ O ₂ S] ⁺ 271 (4.01)	
		CO	[C ₁₃ H ₁₀ N ₂ OS] ⁺ 242 (12.60)	CO	[C ₁₃ H ₁₁ N ₂ OS] ⁺ 243 (4.70)	
		C ₈ H ₇ N ₂	[C ₅ H ₃ OS] ⁺ 111 (100)	C ₆ H ₃ NOS	[C ₇ H ₈ N] ⁺ 106 (9.80)	
		CO	[C ₄ H ₃ S] ⁺ 83 (9.10)	NH	[C ₇ H ₇] ⁺ 91 (15.50)	
2c	[C ₁₆ H ₁₃ N ₂ ClO ₄ S] ⁺ 364 (11.30)	C ₂ H ₅ OH	[C ₁₄ H ₇ N ₂ ClO ₃ S] ⁺	C ₂ H ₄ O	[C ₁₄ H ₉ N ₂ ClO ₃ S] ⁺	366(M ⁺ +2,5.2), 350(5.5), 349(4.8), 292(2.9), 289(4.7), 279(2.7), 264(2.4), 261(5.8), 209(2.5), 208 (2.7), 153 (5.3), 152 (2.5), 140 (1.5), 139 (5.8), 125(3.4), 112(7.3), 110(1.8), 99(10.2), 91(2.9), 90(7.3), 84(2.8), 82(2.2), 76(1.9), 65(2.2), 64(5.7), 63(8.9), 54(6.1), 51(12.7)
		CO	318 (9.30) [C ₁₃ H ₇ N ₂ ClO ₂ S] ⁺	CHO	320 (5.30) [C ₁₃ H ₈ N ₂ ClO ₂ S] ⁺	
		CO	290 (7.30)	CO	291 (6.30)	
		C ₇ H ₄ CIN ₂	[C ₁₂ H ₇ N ₂ ClOS] ⁺ 262 (7.40)	C ₆ H ₃ NOS	[C ₁₂ H ₈ N ₂ ClOS] ⁺	
		CO	[C ₅ H ₃ OS] ⁺ 111 (100) [C ₄ H ₃ S] ⁺ 83 (19.10)	NH	263 (3.00) [C ₆ H ₅ NCl] ⁺ 92 (22.30) [C ₆ H ₄ Cl] ⁺ 111 (100) [C ₆ H ₃] ⁺ 75 (7.00)	
4a	[C ₂₀ H ₁₄ N ₄ O ₂ S] ⁺ 374 (72.20)	C ₁₅ H ₁₁ N ₄ O	[C ₅ H ₃ OS] ⁺ 111 (100)	C ₅ H ₃ OS	[C ₁₅ H ₁₁ N ₄ O] ⁺ 263 (4.40)	375(M ⁺ +1,25.3), 373(13.7), 357 (13.8), 356(7.0), 342(3.2), 341(14.2), 269(2.7), 254(3.5), 242(2.6), 241(9.5), 234(1.7), 213(5.0), 208 (3.5), 206(3.0), 197(2.2), 176(7.8), 175(53.4), 174(5.7), 172(23.4), 158(2.0), 157(1.5), 144(2.8), 143 (2.5), 117(2.5), 116(1.5), 91(8.0), 84(3.2), 76(4.0), 65(38.1), 64(11.0), 51(15.5)
		CO	[C ₄ H ₃ S] ⁺ 83 (19.10)	CO	[C ₁₄ H ₁₁ N ₄] ⁺ 235 (2.7)	
				C ₇ H ₄ N ₂	[C ₇ H ₇ N ₂] ⁺ 119 (1.4)	
				HCN	[C ₆ H ₆ N] ⁺ 92 (27.70)	
				NH	[C ₆ H ₅] ⁺ 77 (33.20)	
4b	[C ₂₁ H ₁₆ N ₄ O ₂ S] ⁺ 388 (48.00)	C ₁₆ H ₁₃ N ₄ O	[C ₅ H ₃ OS] ⁺ 111 (100)	C ₅ H ₃ OS	[C ₁₆ H ₁₃ N ₄ O] ⁺ 277 (1.40)	389(M ⁺ +1, 12.6), 371(10.2), 370 (5.2), 355(13.5), 297(3.2), 276(1.8), 248(2.0), 241(9.9), 240(5.3), 234(3.0), 223(2.2), 213(4.4), 212 (3.4), 206(3.2), 205(3.1), 197(2.4), 190(6.3), 189(50.8), 188(6.4), 174(4.5), 173(4.8), 172(21.2), 156 (2.0), 145(3.1), 144(3.8), 143(4.1), 129(2.3), 118(2.7), 117(3.2), 116(3.0), 107(4.6), 90(13.6), 84(3.1), 66(13.3), 51(10.3)
		CO	[C ₄ H ₃ S] ⁺ 83 (19.60)	CO	[C ₁₅ H ₁₃ N ₄] ⁺ 249 (4.2)	
				C ₇ H ₄ N ₂	[C ₈ H ₉ N ₂] ⁺ 133 (1.2)	
				HCN	[C ₇ H ₈ N] ⁺ 106 (17.70)	
				NH	[C ₇ H ₇] ⁺ 91 (26.80)	
		C ₂ H ₂	[C ₅ H ₅] ⁺ 65 (20.00)			

4c	$[\text{C}_{20}\text{H}_{13}\text{N}_4\text{ClO}_2\text{S}]^+$ 408.5 (11.50)	$\text{C}_{15}\text{H}_{10}\text{N}_4\text{ClO}$ CO	$[\text{C}_5\text{H}_3\text{OS}]^+$ 111 (100) $[\text{C}_4\text{H}_3\text{S}]^+$ 83 (16.10)	$\text{C}_5\text{H}_3\text{OS}$ CO $\text{C}_7\text{H}_4\text{N}_2$ HCN NH HCl	$[\text{C}_{15}\text{H}_{10}\text{N}_4\text{ClO}]^+$ 297 (1.30) $[\text{C}_{14}\text{H}_{10}\text{N}_4\text{Cl}]^+$ 269 (3.1) $[\text{C}_7\text{H}_6\text{N}_2\text{Cl}]^+$ 153 (1.2) $[\text{C}_6\text{H}_5\text{NCl}]^+$ 126 (12.20) $[\text{C}_6\text{H}_4\text{Cl}]^+$ 111 (100) $[\text{C}_6\text{H}_3]^+$ 75 (9.40)	410($\text{M}^++2,41.5$), 407(11.7), 390(3.3), 375(3.8), 374(2.9), 373(2.0), 268(2.0), 254(2.8), 253(3.5), 251(3.4), 250(2.9), 241(7.6), 240(6.6), 213(3.5), 212(3.0), 211(6.6), 210(8.0), 209(17.5), 208(18.2), 187(1.6), 186(5.6), 185(4.9), 173(7.8), 172(17.5), 171(20.8), 158(1.4), 157(3.5), 144(4.8), 125(16.0), 118(3.5), 113(10.4), 110(84.4), 98(16.5), 82(12.6), 90(16.9)
5	$[\text{C}_{22}\text{H}_{16}\text{N}_4\text{O}_3\text{S}]^+$ 416 (23.00)	$\text{C}_5\text{H}_3\text{OS}$ $\text{C}_6\text{H}_6\text{N}$ CH_2CO HCN CN CO	$[\text{C}_{17}\text{H}_{13}\text{N}_4\text{O}_2]^+$ 305 (100) $[\text{C}_{11}\text{H}_7\text{N}_3\text{O}_2]^+$ 213 (8.80) $[\text{C}_9\text{H}_5\text{N}_3\text{O}]^+$ 171(5.1) $[\text{C}_8\text{H}_4\text{N}_2\text{O}]^+$ 144(13.1) $[\text{C}_7\text{H}_4\text{NO}]^+$ 118(5.1) $[\text{C}_6\text{H}_4\text{N}]^+$ 90(26.7)	$\text{C}_{17}\text{H}_{13}\text{N}_4\text{O}_2$ CO	$[\text{C}_5\text{H}_3\text{OS}]^+$ 111 (20.90) $[\text{C}_4\text{H}_3\text{S}]^+$ 83 (9.90)	417($\text{M}^++1,13.1$), 374(44.1), 373(34.2), 358(3.7), 57(70.1), 347(15.8), 346(11.0), 306(40.4), 273(5.6), 254(8.8), 243(6.1), 241(12.8), 214(4.0), 74(11.2), 173(12.3), 72(31.6), 159(5.3), 155(5.9), 143(4.3), 135(8.6), 134(6.4), 131(6.7), 130(8.8), 128(6.7), 119(4.0), 117(4.8), 110(8.0), 105(5.3), 92(26.7), 91(13.4), 84(2.1), 77(17.9), 65(93.0), 63(2.9), 52(7.5).



Scheme 3. Mass fragmentation pattern of compound 2b



Scheme 4. Mass fragmentation pattern of compound 4a

The molecular ion peak of compound **5** was observed at m/z 416 (Fig. 3), corresponding to the molecular formula $C_{22}H_{16}N_4O_3S$. The ion peak of compound **5** at m/z 416 fragmented further and involved two possible pathways as illustrated in Scheme 5. The ion of m/z 416 fragmented via the pathway A to give a stable fragmented ion of m/z 305 by losing 2-thionyl radical cation, the ion of m/z 305 fragmented to give an ion of m/z 213, which lost CH_2CO to give a fragmented ion of m/z 171. This fragmentation led to m/z 144, 118, 90 and m/z 64, respectively.

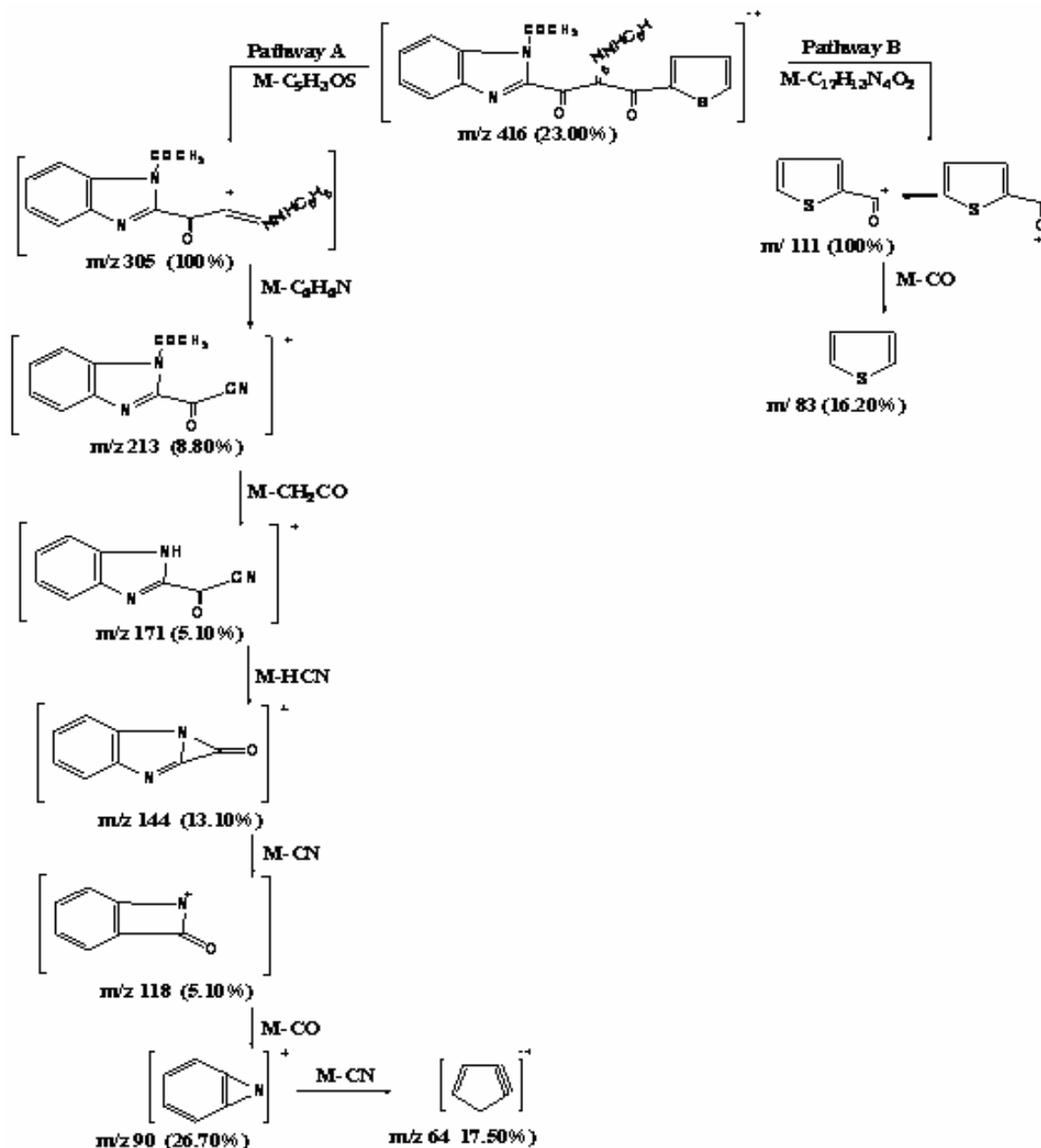
Subsequently, the molecular ion m/z 416 fragmented via the pathway B to give the ion of

m/z 111, which fragmented further to give ion of m/z 83 by losing CO.

Compounds 3, 9a, 9b, 10 and 11

The mass spectra of the synthesized compounds **3**, **9a**, **9b**, **10** and **11** showed intense molecular ion peaks at m/z 270, 360, 388, 294 and m/z 252, consistent with the molecular formulas $C_{14}H_{10}N_2O_2S$, $C_{21}H_{16}N_2O_2S$, $C_{22}H_{16}N_2O_3S$, $C_{16}H_{10}N_2O_2S$ and $C_{14}H_8N_2OS$, respectively.

Table 2 list the m/z (relative abundance, %) values of the principal fragments of the prepared compounds **3**, **9**, **10** and **11** that show relatively strong molecular ion and peaks typical of a cleavage and rearrangement process type fragmentation.



Scheme 5. Mass fragmentation pattern of compound 5

From a study of the mass spectra of compounds **3**, **9a** and **9b**, it was found that the molecular ion for all these compounds fragmented further and involved two various possible pathway as illustrated by scheme 6; however, the molecular ion of compound **3** of m/z 270 (Fig. 4) fragmented via the pathway A to give a stable ion of m/z 111, which fragmented further to give ion of m/z 83 by losing CO. Accordingly, the same ion of m/z 270 was broken via pathway B to give an ion m/z 186 by losing thiophene molecule. The ion at m/z 186

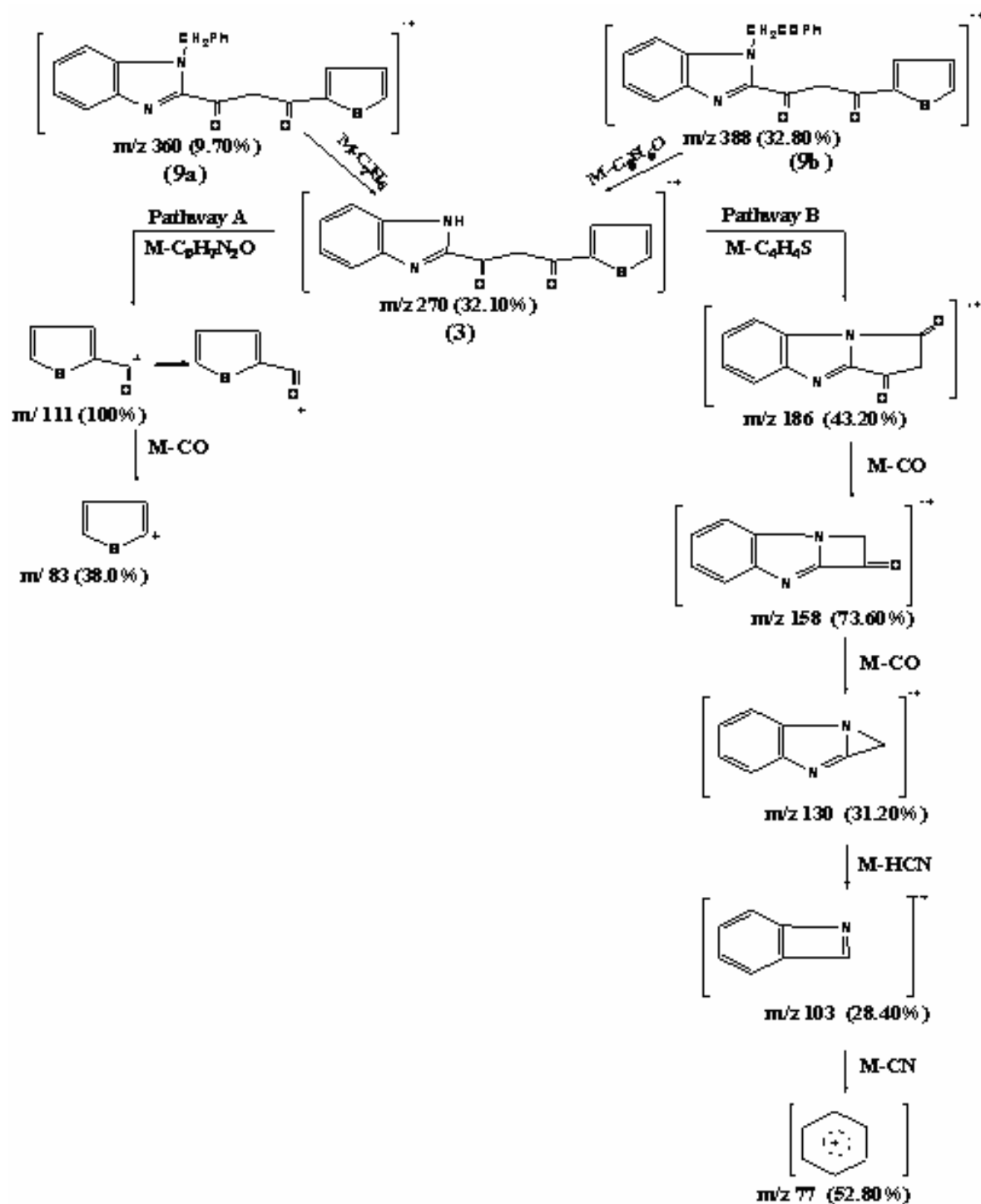
underwent fragmentation to produce peaks at m/z 158, 130 and 103 by losing two carbon monoxide molecule and hydrogen cyanide molecule.

From a study of the mass spectra of compounds **9a** and **9b**, it was found that the molecular ion for these two compounds had fragmented to ion of m/z 270, corresponding to the molecular ion of compound **3** by losing C_7H_6 and C_8H_6O molecular (Figs. 5 and 6) the ion of m/z 270 which has further broken via similar pathway of compound **3**.

Table 2

EI Spectra (70 eV) of compounds 3, 9, 10 and 11

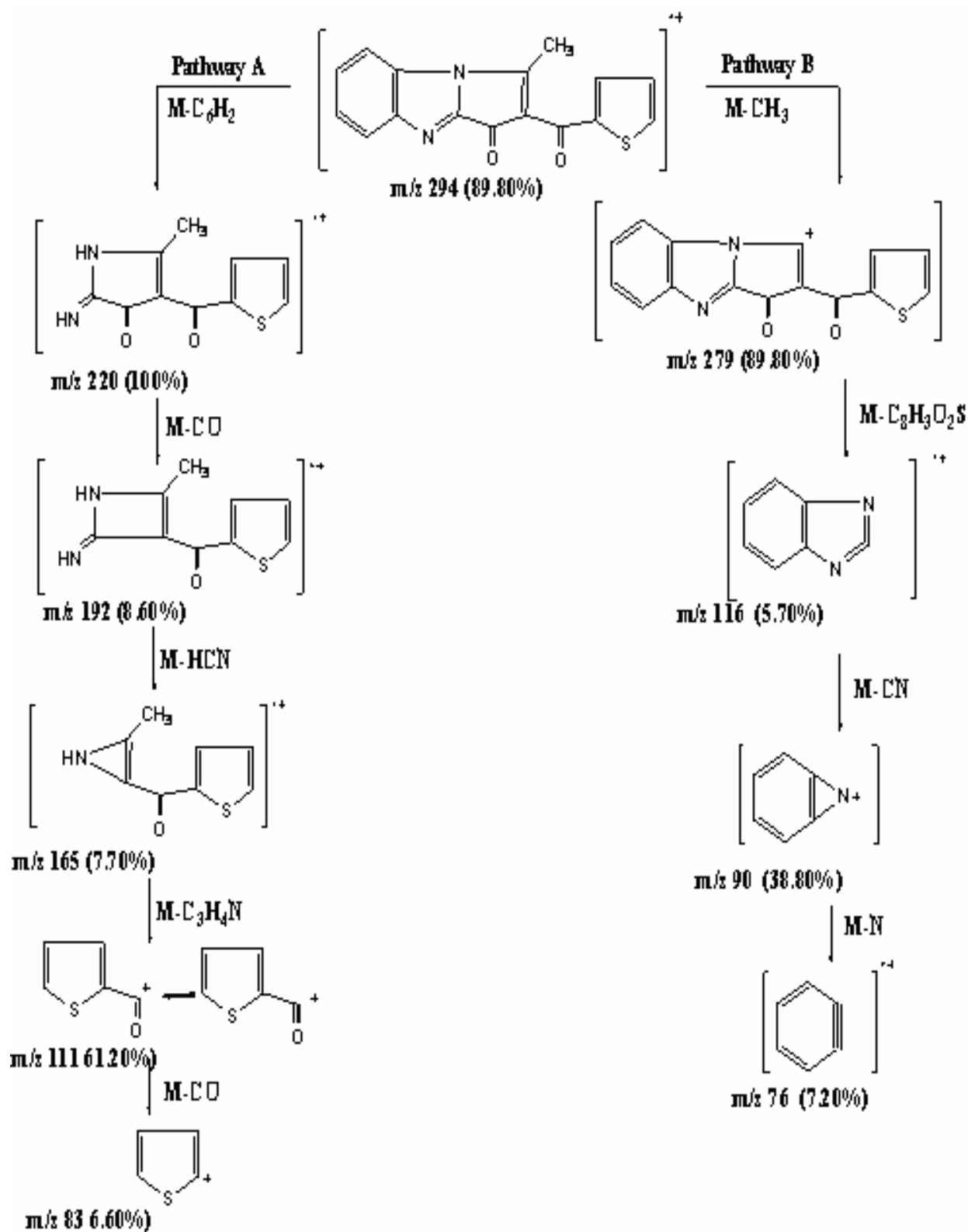
No.	M ⁺	Pathway A		Pathway B		Other ions
		M-	m/z	M-	m/z	
3	[C ₁₄ H ₁₀ N ₂ O ₂ S] ⁺ 270 (32.10)	C ₄ H ₄ S	[C ₁₀ H ₆ N ₂ O ₂] ⁺ 186 (43.20)	C ₉ H ₇ N ₂ O	[C ₅ H ₃ OS] ⁺ 111 (100)	271(M ⁺ +1,17.6), 241(18.5), 160 (23.7), 131(11.1), 109(17.3), 108(12.3), 105(11.2), 104(28.4), 91(64.3), 90(33.3), 84(3.7), 79 (22.2), 78(19.2), 76(18.5), 69 (49.4), 64(32.1), 63(28.4), 57(45.7), 53(40.7), 51(19.8).
		CO	[C ₉ H ₆ N ₂ O] ⁺ 158 (73.60)	CO	[C ₄ H ₃ S] ⁺ 83 (38.30)	
		CO	[C ₈ H ₆ N ₂] ⁺ 130 (31.20)			
		HCN	[C ₇ H ₅ N] ⁺ 103 (28.4)			
		CN	[C ₆ H ₅] ⁺ 77 (52.80)			
9a	[C ₂₁ H ₁₆ N ₂ O ₂ S] ⁺ 360 (9.70)	C ₇ H ₆	[C ₁₄ H ₁₀ N ₂ O ₂ S] ⁺ 270 (100)	C ₇ H ₆	[C ₁₄ H ₁₀ N ₂ O ₂ S] ⁺ 270 (100)	361(M ⁺ +1,4.7), 272(11.4), 271 (23.3), 269(9.8), 241(10.7), 237(10.3), 213(3.8), 198(4.6), 187(13.2), 169(5.8), 159(14.2), 131(12.5), 129(3.7), 112(8.2), 103(12.8), 90(11.3), 84(7.3), 82 (7.6), 78(6.4), 76(9.4), 69(4.9), 68(5.8), 64(13.1), 63(17.5), 58 (13.1), 57(15.3), 53(13.5), 52 (16.1), 51(12.4).
		C ₄ H ₄ S	[C ₁₀ H ₆ N ₂ O ₂] ⁺ 186 (52.00)	C ₉ H ₇ N ₂ O	[C ₅ H ₃ OS] ⁺ 111 (100)	
		CO	[C ₉ H ₆ N ₂ O] ⁺ 158 (26.70)	CO	[C ₄ H ₃ S] ⁺ 83 (38.30)	
		CO	[C ₈ H ₆ N ₂] ⁺ 130 (15.70)			
		CN	[C ₇ H ₆ N] ⁺ 104 (8.00)			
		HCN	[C ₆ H ₅] ⁺ 77 (18.60)			
9b	[C ₂₂ H ₁₆ N ₂ O ₃ S] ⁺ 388 (32.80)	C ₈ H ₆ O	[C ₁₄ H ₁₀ N ₂ O ₂ S] ⁺ 270 (61.50)	C ₈ H ₆ O	[C ₁₄ H ₁₀ N ₂ O ₂ S] ⁺ 270 (100)	389(M ⁺ +1,18.9), 316(3.8), 360 (5.7), 283(8.8), 271(10.6), 269 (9.9), 242(10.3), 241(15.0), 187 (10.7), 131(11.0), 129(3.9), 112 (7.5), 105(53.1), 103(16.8), 91(5.4), 90(12.0), 84(5.8), 82 (3.5), 78(8.2), 76(13.6), 65(10.1), 64(12.5), 63(16.1), 58(9.1), 53(10.1), 52(16.6), 51(41.9).
		C ₄ H ₄ S	[C ₁₀ H ₆ N ₂ O ₂] ⁺ 186 (52.00)	C ₉ H ₇ N ₂ O	[C ₅ H ₃ OS] ⁺ 111 (100)	
		CO	[C ₉ H ₆ N ₂ O] ⁺ 158 (26.70)	CO	[C ₄ H ₃ S] ⁺ 83 (38.30)	
		CO	[C ₈ H ₆ N ₂] ⁺ 130 (15.70)			
		CN	[C ₇ H ₆ N] ⁺ 104 (8.00)			
		HCN	[C ₆ H ₅] ⁺ 77 (18.60)			
10	[C ₁₆ H ₁₀ N ₂ O ₂ S] ⁺ 294 (89.8)	C ₆ H ₂	[C ₁₀ H ₈ N ₂ O ₂ S] ⁺ 220 (100)	CH ₃	[C ₁₅ H ₇ N ₂ O ₂ S] ⁺ 279 (73.70)	295(M ⁺ +1,20.4), 243(57.8), 280 (16.1), 271(2.3), 266(9.8), 265 (7.2), 251(9.1), 237(10.9), 221 (15.6), 219(10.4), 191(22.4), 190(3.8), 163(2.7), 164(5.4), 159(12.9), 147(7.0), 135(6.6), 133(8.8), 112(3.9), 104(10.0), 84(12.0), 82(3.0), 77(16.50), 64 (15.0), 63(28.1), 52(7.0), 51 (16.5)
		CO	[C ₉ H ₈ N ₂ OS] ⁺ 192 (8.60)	C ₈ H ₃ O ₂ S	[C ₇ H ₄ N ₂] ⁺ 116 (5.70)	
		HCN	[C ₈ H ₇ NOS] ⁺ 165 (7.70)	CN	[C ₆ H ₄ N] ⁺ 90 (38.80)	
		C ₃ H ₄ N	[C ₅ H ₃ OS] ⁺ 111 (61.2)	N	[C ₆ H ₄] ⁺ 76 (7.20)	
		CO	[C ₄ H ₃ S] ⁺ 83 (6.60)			
11	[C ₁₄ H ₈ N ₂ OS] ⁺ 252 (77.4)	CO	[C ₁₃ H ₈ N ₂ S] ⁺ 224 (29.00)	CO	[C ₁₃ H ₈ N ₂ S] ⁺ 224 (29.00)	253(M ⁺ +1,13.8) 135(6.7), 134 (16.5), 126(9.8), 112(7.1), 111 (21.5), 91(7.4) 89(8.8), 88(10.4), 83(9.1), 75(16.2), 64(29.0), 63(36.7), 62(34.3), 61 (11.8), 58 (35.4), 57(15.8), 52 (16.8), 51 (24.9).
		C ₆ H ₄ S	[C ₇ H ₄ N ₂] ⁺ 116 (7.40)	C ₇ H ₄ N ₂	[C ₆ H ₄ S] ⁺ 108 (100)	
		CN	[C ₆ H ₄ N] ⁺ 90 (32.00)	C ₂ H ₂	[C ₄ H ₂ S] ⁺ 82 (16.80)	
		N	[C ₆ H ₄] ⁺ 76 (14.10)			
		C ₂ H ₂	[C ₄ H ₂] ⁺ 50 (22.00)			



Scheme 6. Mass fragmentation pattern of compounds 3, 9a and 9b

The molecular ion of compound **10** at m/z 294 fragmented further and involved two different possible pathways, as illustrated by Scheme 7 (Fig 7). The molecular ion of compound **11** fragmented and involved two pathways as illustrated in Table 2 (Fig. 8).

The electron impact ionization mass spectra of compounds **10** and **11** show a base peak of m/z 220 and m/z 108, while the base peak of compounds **2b**, **3**, **4a** and **9b** is the ion of m/z 111. The mass spectra of compound **5** show a base peak of m/z 305, while the base peak of compound **9a** is the molecular ion of compound **3** of m/z 270.



Scheme 7. Mass fragmentation pattern of compound 10

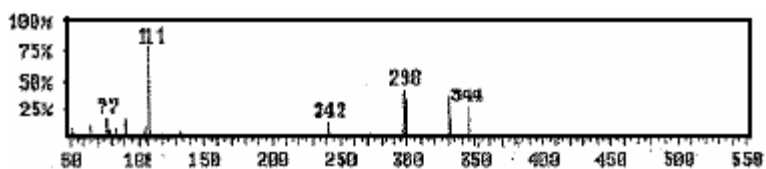


Fig. 1. Mass fragmentation of compound 2b

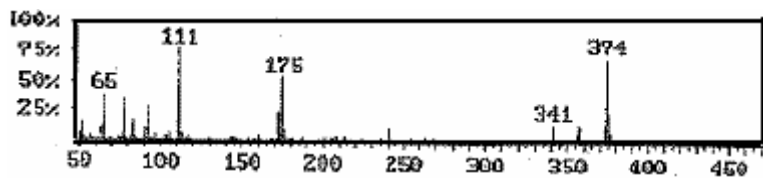


Fig. 2. Mass fragmentation of compound 4a

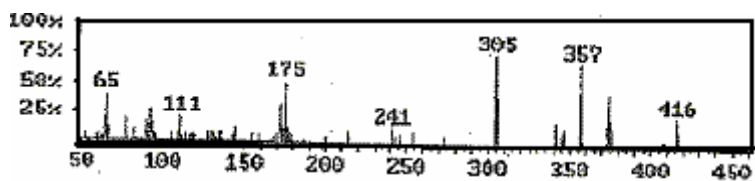


Fig. 3. Mass fragmentation of compound 5

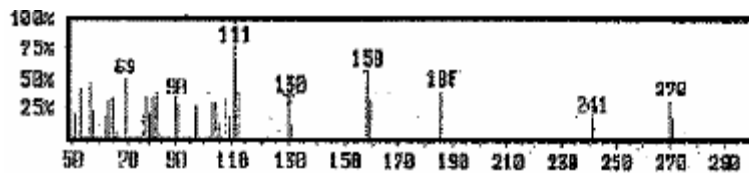


Fig. 4. Mass fragmentation of compound 3

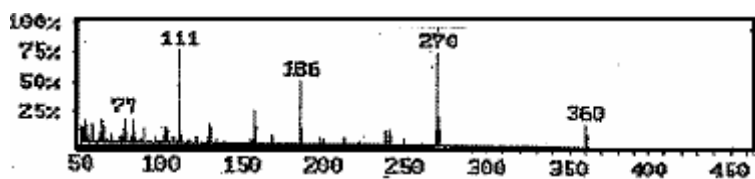


Fig. 5. Mass fragmentation of compound 9a

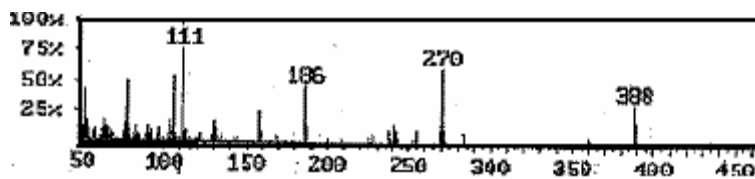


Fig. 6. Mass fragmentation of compound 9b

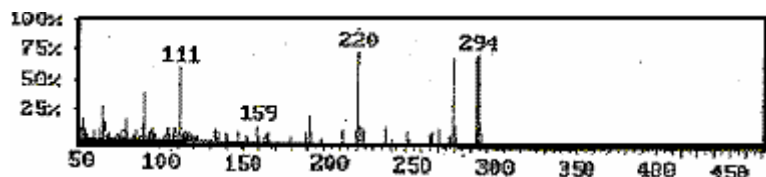


Fig. 7. Mass fragmentation of compound 10

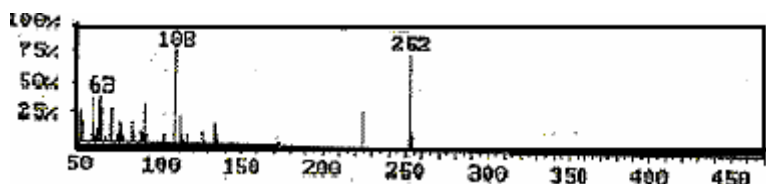


Fig. 8. Mass fragmentation of compound 11

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