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ANTIMICROBIAL ACTIVITY OF THE REACTION PRODUCTS OF 2-ACETYL- AND 2-(2,2-DICYANO-1-METHYLVINYL)NAPHTHO[2,1-b] FURAN WITH SOME NUCLEOPHILIC AND ELECTROPHILIC REAGENTS

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Abstract

The reaction of 2-acetyl and 2-(2,2-dicyano-1-methylvinyl)naphtho[2,1-b]furan with malononitrile, phenylhydrazine, α-cyanocinnamonitriles, anisaldehyde and other differenet reagents were discussed. The structure of the reaction products were supported by ^{1}HNMR, ^{13}CNMR, IR and mass spectra data. The biological activity of the compounds cited in this article were reported.

Keywords:2-Acetylnaphtho[2,1-*b*]furan, 2-(2,2-dicyano-1-methylvinyl)naphtho[2,1-b]-furan, 3-[(4-methoxyphenyl)- and 3-[(3-bromo-4-methoxyphenyl)-1-naphtho[2,1-b]fur-an-2-yl]prop-2-en-1-one and antimicrobial activity.

Introduction

Many substituted benzofurans and naphthofurans show marked biological[1-5] and pharmacological[6-9] activities. The wide pharmacological potential of these bioactive moieties has attracted many organic and medicinal chemists to develop efficient routs for their syntheses. In continuation of our previous work [10-14] on the synthesis of new heterocyclic compounds, we report here the novel synthesis of naphtha[2,1-*b*]furan derivatives to evaluate the antimicrobial activity.

Experimental

Melting points were measured by melting point apparatus (Stuart Scientific Co., UK) and remained uncorrected. The IR spectra were recored on a Shimadzu IR 440,

spectrophotometer (Shimadzu, Japan) in KBr. ^{1}H NMR and ^{13}C NMR spectra were measured on a Varian Mercury (300 MHz) spectrometer (Varian, UK), using TMS as an internal standard and DMSO-d_6 as solvent. Mass spectra were run on a Shimadzu GC-MS QP 1000 EX mass spectrometer. Microanalytical data were obtained from Microanalytical Unit at Center, Faculty of Science, Cairo University (Egypt) (Tabel 1), Paper discs manufactured by Bristol-Myers Squibb, Giza, Egypt.

Synthesis of 2-Acetylnaphtho[2,1-b]furan (3)

A mixture of 2-hydroxy-1-naphthaldehyde **(1)** (0.01 mol), chloroacetone **(2)** (0.01 mol) and anhydrous potassium carbonate (0.02 mol) in anhydrous acetone (50 ml) were refluxed for 8 hour. The mixture allowed to cool and poured onto crushed ice (50 g) and water (100 ml) then acidified with conc. HCl. The solid product formed was filtered and washed with water to give **3** as yellow crystals (ethanol, m.p. 108-110 ºC, yield 90 %) [lit[15] m.p.113-114 ºC].

Synthesis of 2-(2,2-dicyano-1-methylvinyl)naphtho[2,1-b]furan (4)

A solution of 2-acetylnaphtho[2,1-*b*]furan **(3)** (0.01 mol) in dry benzene (100 ml), malononitrile (0.01 mol), ammonium acetate (2 g) and acetic acid (2 ml). The reaction mixture was refluxed using Dean and Stark apparatus until water collected. The product obtained was recrystallized to give **4** as yellow crystals (benzene, m.p. 224-226 ºC, yield 81 %).

***Synthesis of 2-(1-phenylhydrazonoethyl)naphtho[2,1-b]furan* (6)**

Method A.- A mixture of **4** (0.01 mol) and phenylhydrazine (0.01 mol) in ethanol (50 ml) was refluxed for 2h. The solid product formed was collected to give **6** as yellow crystals (ethanol, m.p. 172-173 ºC, yield 81 %).

***Method B.*-** A solution of **3** (0.01 mol) and phenylhydrazine (0.01 mol) in ethanol (50 ml) was refluxed for 2 h to give **6** (yield 83 %).

Synthesis of 2-(5-amino-4-cyano-3-thienyl)naphtho[2,1-b]furan (7)

A mixture of **4** (0.01 mol), elemental sulfur and ethanol (50 ml) in a few drops of triethylamine was refluxed for 3h. The obtained product was filtered off to give **7** as yellow crystals (dioxane, m.p. 220-222 ºC, yield 80 %).

Synthesis of 2-(1-naphtho[2,1-b]furan-2-yl-2-phenylazovinyl)malononitrile (8b)

To a cold solution of **4** (0.01 mol) in pyridine (20 ml) was added benzenediazonium chloride (0.01 mol) [prepared by diazotization of aniline (0.01 mol) in HCl (6 M, 6 ml) with sodium nitrite (0.7 g) at 0-5ºC] portion wise over 30 min with constant stirring. After complete addition, the reaction mixture was stirred for a further 2h at 0-5ºC. The solid product was filtered, washed with water, dried to give **8b** as pale yellow crystals (ethanol, m.p. 173-175 ºC, yield 75 %).

Synthesis of 2-(5-acetylamino-4-cyano-3-thienyl)naphtho[2,1-b]furan (9)

A mixture of **7** (0.01 mol), triethyl orthoformate (0.01 mol) in acetic anhydride (20 ml) was heated under reflux for 3h. The obtained product was filtered to give **9** as pale yellow crystals (benzene, m.p. 250-252 ºC, yield 88 %).

Synthesis of 2-(5-formylamino-4-cyano-3-thienyl)naphtho[2,1-b]furan (11)

A mixture of **7** (0.01 mol), formic acid (0.01 mol) was heated under reflux for 3h. The obtained product was filtered to give **11** as brown crystals (benzene, m.p. 295-297 ºC, yield 85 %).

Synthesis of naphtho[2,1-b]furan derivatives (16a-c). General procedure

A mixture of **4** (0.01 mol), substituted α-cyanocinnamonitriles **(13a-c)** or substituted ethyl α-cyanocinnamates **(13d-f)** (0.01 mol) in absolute ethanol (30 ml) and few drops of piperidine was refluxed for 3h. The solid product formed was collected by filtration and recrystallized from the proper solvent to give **16a-c.**

2-(3-Amino-2,4-dicyano-5-phenyl)naphtho[2,1-b]furan (16a).- The product was obtained as yellow needles (benzene/ethanol, m.p. 292-294 ºC, yield 65 %).

2-[3-Amino-2,4-dicyano-5-(4-methylphenyl)]naphtho[2,1-b]furan (16b).- The product was obtained as yellow needles (benzene, m.p. 302-303 ºC, yield 70 %).

2-[3-Amino-2,4-dicyano-5-(4-methoxyphenyl)]naphtho[2,1-b]furan (16c).- The product was obtained as yellow crystals (benzene, m.p. 302-303 ºC, yield 68 %).

Synthesis of 3-[(4- Methoxyphenyl)-1-naphtho[2,1-b]furan-2-yl]prop-2-en-1-one (18)

A stream of dry HCl gas was passed through a mixture of **3** (0.01 mol), 4-methoxybenzaldhyde (0.01 mol) in ethanol (30 ml), the reaction mixture was stirred

for a further 2h. The solid product was collected by filtration to give **18** as yellow crystals (ethanol, m.p. 178-180 ºC, yield 76 %).

Synthesis of 3-[(3-Bromo-4-methoxyphenyl)-1-naphtho[2,1-b]furan-2-yl]prop-2-en-1-one (19)

To a stirred solution of chalcone **18** (0.01 mol) in glacial acetic acid (30 ml), bromine (0.01 mol) was added. The reaction mixture was stirred for 2h at sun light and then the mixture was poured onto crushed ice (50 g) and water (100 ml) and the solid product was formed filtered and washed with water to give **19** as yellow crystals (ethanol, m.p. 178-180 ºC, yield 73 %).

Synthesis of pyrazole derivatives (20a, b). General procedure

A mixture of chalcone **18** (0.01 mol) and hydrazine hydrate or phenyl hydrazine (0.01 mol) in ethanol (30 ml) was refluxed for 2h. The solid product was collected by filtration and recrystallized from the proper solvent to give **20a,b**.

5-(4-Methoxyphenyl)-3-naphtho[2,1-b]furan-2-yl-4,5-dihydro-1H-pyrazole (20a).- Compound **20a** was obtained as pale yellow crystals (ethanol, m.p. 150-152 ºC, yield 87 %).

5-(4-Methoxyphenyl)-3-naphtho[2,1-b]furan-2-yl-1-phenyl-4,5-dihydro-1H-pyrazole (20b).- Compound **20b** was obtained as yellow needles (ethanol, m.p. 155-156 ºC, yield 90 %).

Synthesis of 4-(4-Methoxyphenyl)-6-naphtho[2,1-b]furan-2-yl-1H-pyrimidine-2-thione (21)

A mixture of chalcone **18** (0.01 mol) and thoiurea (0.01 mol) in ethanolic C_2H_5ONa solution (0.25 g Na in 30 ml abs. ethanol) was heated under reflux for 3h. The precipitate solid was collected by filtration to give **21** as yellow crystals (benzene, m.p. 205-207 ºC, yield 81 %).

Synthesis of 4-(4-Methoxyphenyl)-6-naphtho[2,1-b]furan-2-yl-2-thioxo-1,2-dihydro-pyridine-3-carbonitrile (22)

A mixture of chalcone **18** (0.01 mol) and cyanothioacetamide (0.01 mol) in ethanol (30 ml) and few drops of piperidine was refluxed for 3h. The solid product was collected by filtration to give **22** as yellow needles (DMF, m.p. 340-342 ºC, yield 81 %).

Table I. Elemental analyses of newly synthesized compounds

Comp. No.	Molecular Formula (M)	Analysis (%)Found/calculated		
		C	H	N
3	$C_{14}H_{10}O_2$	79.95	4.78	——
	(210)	79.98	4.79	
4	$C_{17}H_{10}N_2O$	79.04	3.88	10.82
	(258)	79.06	3.90	10.85
6	$C_{20}H_{16}N_2O$	79.96	5.35	9.30
	(300)	79.98	5.37	9.33
7	$C_{17}H_{10}N_2OS$	70.30	3.45	9.62
	(290)	70.33	3.47	9.65
8b	$C_{23}H_{14}N_4O$	76.20	3.87	15.45
	(362.)	76.23	3.89	15.46
9	$C_{19}H_{12}N_2O_2S$	68.65	3.62	8.40
	(332)	68.66	3.64	8.43
11	$C_{18}H_{10}N_2O_2S$	67.85	3.10	8.75
	(318)	67.91	3.17	8.80
16a	$C_{26}H_{15}N_3O$	80.95	3.90	10.85
	(385)	81.02	3.93	10.90
16b	$C_{27}H_{17}N_3O$	81.00	4.25	10.50
	(399)	81.19	4.29	10.52
16c	$C_{27}H_{17}N_3O_2$	78.00	4.00	10.00
	(415)	78.06	4.12	10.11
18	$C_{22}H_{16}O_3$	80.40	4.85	——
	(328)	80.47	4.91	
19	$C_{22}H_{15}BrO_3$	64.80	3.65	——
	(407)	64.88	3.71	
20a	$C_{22}H_{18}N_2O_2$	77.00	5.25	8.12
	(342)	77.17	5.30	8.18
20b	$C_{28}H_{22}N_2O_2$	80.30	5.25	6.62
	(418)	80.36	5.30	6.69
21	$C_{23}H_{16}N_2O_2S$	71.80	4.12	7.20
	(384)	71.85	4.19	7.29
22	$C_{25}H_{16}N_2O_2S$	73.40	3.90	6.80
	(408)	73.51	3.95	6.86

Antibacterial Activity:

Eleven compounds were screened *in vitro* for their antimicrobial activities against two species of Gram-positive bacteria *Bacillus Subtilis* (ATCC-7972) (BS), *Staphylococcus Aurous* (NCTC-7447) (SA) and three Gram-negative bacteria *Escherichia Coli* (NCTC-10416) (EC), *Pseudomonas Aeuroginosa* (ATCC-10415) (PA), *Candida Albican* (IMRU-3669) (CA) and one fungi *Aspergillus Niger* (ATCC-6275) (AN) microorganisms using the paper disc diffusion method[16,17] .

The tested compounds were dissolved in *N,N*-dimethylformamide (DMF) to get a solution of 1 mg ml^{-1}. the inhibition zones were measured in millimeters at the end of an incubation period of 48 h at 28 ^{o}C. *N,N*-dimethylformamide (DMF) showed no inhibition zones. Neomycin standard antibiotic was used as a reference to evaluate the potency of the tested compounds. The inhibition zone of microbial growth produced by different compounds are reported in Table II.

Table II Antibacterial and antifungal activities of newly synthesized compounds

Compd. No.	Inhibition zone diameter in mm					
	BS ATCC 7972	**SA NCTC 7447**	**EC NCTC 10416**	**PA ATCC 10415**	**CA IMRU 3669**	**AN ATCC 627**
3	- ve	- ve	- ve	- ve	- ve	- ve
6	++ ve	++ ve	++ ve	++ ve	- ve	- ve
7	+ ve	+ ve	+ ve	+ ve	- ve	- ve
8b	- ve	- ve	- ve	- ve	- ve	- ve
9	- ve	- ve	- ve	- ve	- ve	- ve
11	- ve	- ve	- ve	- ve	- ve	- ve
16b	- ve	- ve	- ve	- ve	- ve	- ve
18	- ve	- ve	- ve	- ve	- ve	- ve
19	+ ve	+ ve	+ ve	+ ve	- ve	- ve
20a	- ve	- ve	- ve	- ve	- ve	- ve
20b	- ve	- ve	- ve	- ve	- ve	- ve
21	- ve	- ve	- ve	- ve	- ve	- ve
Neomycine (30 mg mL^{-1})	+++ ve	+++ ve	+++ ve	+++ ve	+++ ve	+++ ve

- ve (no inhibition zone)
+ ve (when inhibition zone up to 8 mm)
++ ve (when inhibition was between 8-12 mm)
+++ ve (when inhibition was between 12-15 mm)

Conclusions

The compound **6** showed moderate inhibition (++ ve inhibition zone was between 8-12 mm) against *Bacillus Subtilis*, *Staphylococcus Aurous*, *Escherichia Coli* and *Pseudomonas Aeuroginosa*. The compound **7** showed weak inhibition (+ ve

inhibition zone up to 8 mm) against *Bacillus Subtilis*, *Staphylococcus Aurous*, *Escherichia Coli* and *Pseudomonas Aeuroginosa*, the remaining tested compounds showed no activities against all the test microoganisms.

Results And Discussion

Treatment of 2-hydroxy-1-naphthaldehyde **(1)** with chloroacetone **(2)** in refluxing acetone in the presence of anhydrous potassium carbonate gave the 2-acetylnaphtho-

[2,1-*b*]furan **(3).**

Condensation of 2-acetylnaphtho[2,1-*b*]furan **(3)** with malononitrile in boiling benzene containing ammonium acetate and acetic acid afforded 2-(2,2-dicyano-1-methylvinyl)naphtho[2,1-*b*]furan **(4)** (Scheme 1).

In contrast to the anticipated formation of pyrazoline derivatives **5**[18], the reaction of **4** with phenylhydrazine in boiling ethanol gave the imino compound **6** and is assumed to proceed via elimination of malononitrile. The proposed structure for **6** was supported by its independent synthesis from **3** by refluxing with phenylhydrazine in boiling ethanol (m.p. and mixed m.p.) (Scheme 1).

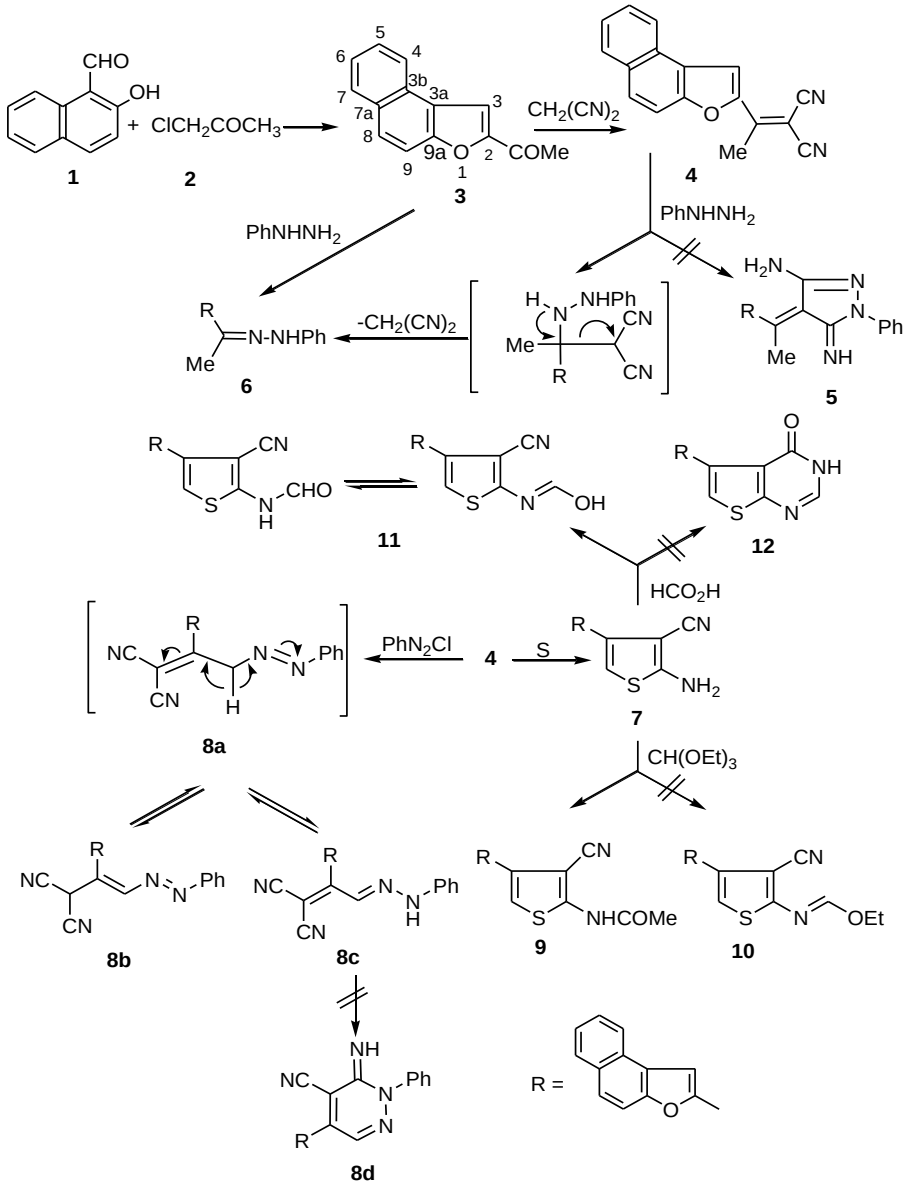
Interaction of **4** with sulfur via Gewald reaction[19] produced 2-(5-amino-4-cyano-3-thienyl)naphtho[2,1-*b*]furan **(7)** while with benzene diazonium chloride afforded the open chain product **8b** instead of the closed product 2,3-dihydro-3-imino-5-(naphtho[2,1-*b*]furan-2-yl)-2-phenylhydrazine-4-carbonitrile **(8d)**. The proposed closed structures **8d** was ruled out on the bases of spectroscopic data (Scheme 1).

Treatment of **7** with triethyl orthoforamte in acetic anhydride at reflux afforded the N-acetylamino derivative **9** instead of the 2-(5-ethoxymethyleneamino-4-cyano-3-thienyl)naphtho[2,1-*b*]furan **(10)**, while with formic acid gave the N-formylamino derivative **11** instead of the pyrimidine derivative **12** (Scheme 1). Structures **3, 4, 6, 7, 8b, 9** and **11** were estabished by spectral data (Table III).

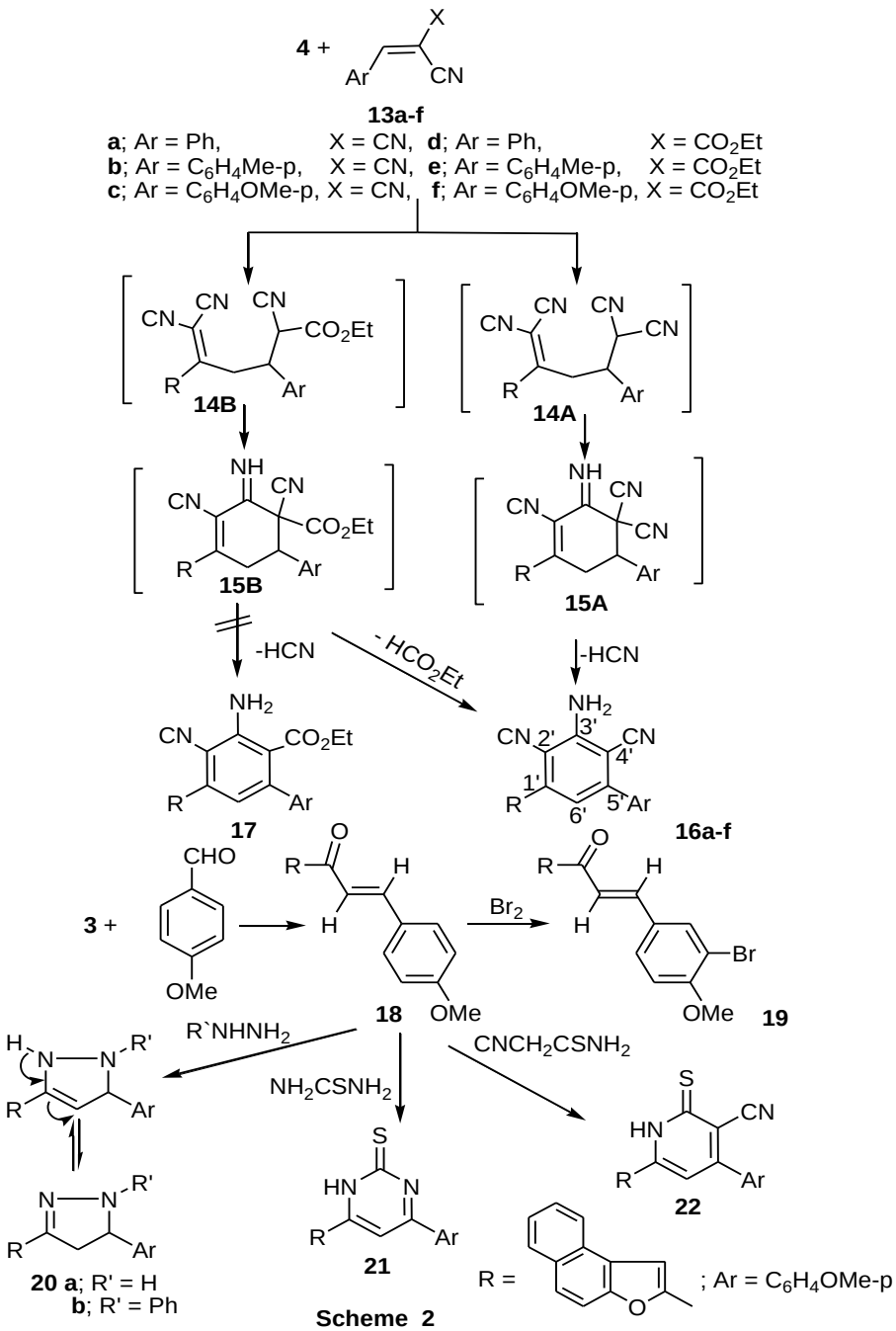
Interaction of **4** with various substituted α-cyanocinnamonitriles **(13a-f)** in boiling ethanol containing a few drops of piperidine, afforded 2-(3-amino-2,4-dicyano-5-arylphenyl)naphtho[2,1-*b*]furan **(16a-c)** (Scheme 2).

The formation of **16a-c** from the reaction of **4** and **13a-c** was assumed to proceed via a Michael type addition of the methyl function in **4** to the activated double bond to yield the acyclic Michael adduct **14A** which then cyclizes into **(15A)**. The latter readily loses HCN to yield the final isolable thermodynamically stable compounds

(16a-c) (Scheme 2). In contrast to the anticipated formation of the esters **17d-f**, the reaction of **4** with various substituted ethyl α-cyanocinnamates **(13d-f)** afforded **16a-c** and were assumed to proceed via elimination of ethyl formate from the intermediate **(15B)**[20] (Scheme 2).



Scheme 1


4 +
13a-f
a; Ar = Ph, X = CN, d; Ar = Ph, X = CO2Et
b; Ar = C6H4Me-p, X = CN, e; Ar = C6H4Me-p, X = CO2Et
c; Ar = C6H4OMe-p, X = CN, f; Ar = C6H4OMe-p, X = CO2Et
14B
14A
15B
15A
-HCN
- HCO2Et
17
16a-f
3 +
18
Br2
19
R`NHNH2
NH2CSNH2
CNCH2CSNH2
20 a; R' = H
b; R' = Ph
21
22
R =
; Ar = C6H4OMe-p

Scheme 2

The high reactivity of α,β-unsaturated ketones attracted several authors to investigate their chemical importance in organic synthesis and for their biological properties[21,22] .

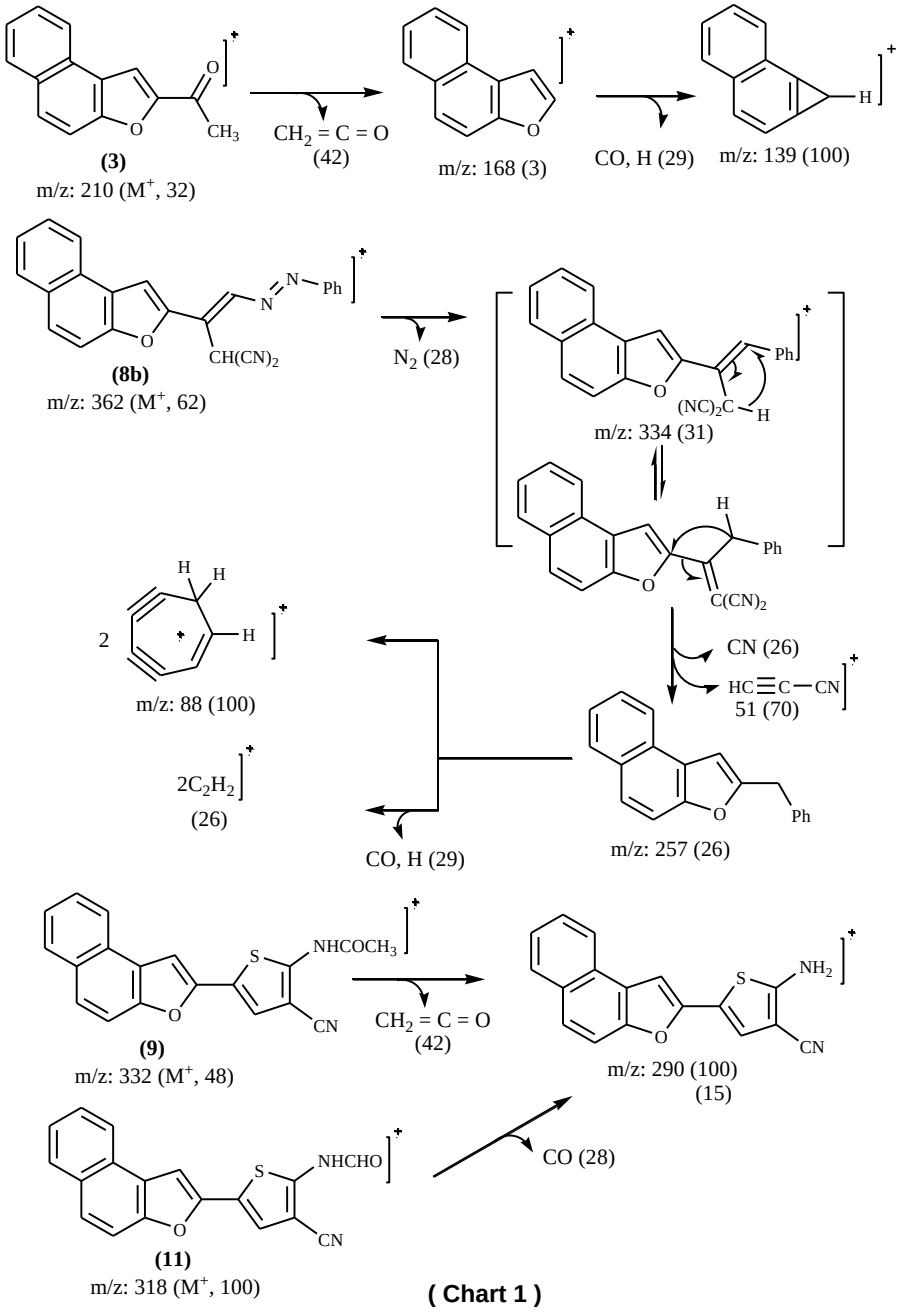
Thus, the chalcone **18** was prepared by condensation of **3** with p-anisaldehyde in the presence of dry HCl gas in ethanol, while bromination of **18** afforded 3-[(3-bromo-4-methoxyphenyl)naphtho[2,1-*b*]furan-2-yl]prop-2-en-1-one **(19)** (Scheme 2). The bromine was introduced in active aryl moiety rather than the α,β-unsaturated double bond.

Treatment of the chalcone **18** with hydrazine hydrate and phenylhydrazine in refluxing ethanol afforded 5-(4-Methoxyphenyl)-3-(naphtho[2,1-b]furan-2-yl)-4,5-di- hydro-1H-pyrazole **(20a)** and 5-(4-Methoxyphenyl)-3-(naphtho[2,1-*b*]furan-2-yl)-1-phenyl-4,5-dihydro-1H-pyrazole **(20b)** respectively (Scheme 2), while with thiourea or cyanothioacetamide gave 4-(4-methoxyphenyl)-6-(naphtho[2,1-*b*]furan-2-yl)pyramid-ine-2(1H)-thione **(21)** and 1,2-dihydro-4-(4-methoxyphenyl)-6-(naphtho[2,1-*b*] furan-2-yl)-2-thioxopyridine-3-carbonitrile **(22)** respectively (Scheme 2). Structures **16a-c, 18, 19, 20a,b, 21** and **22** were established by spectral data (Table III).

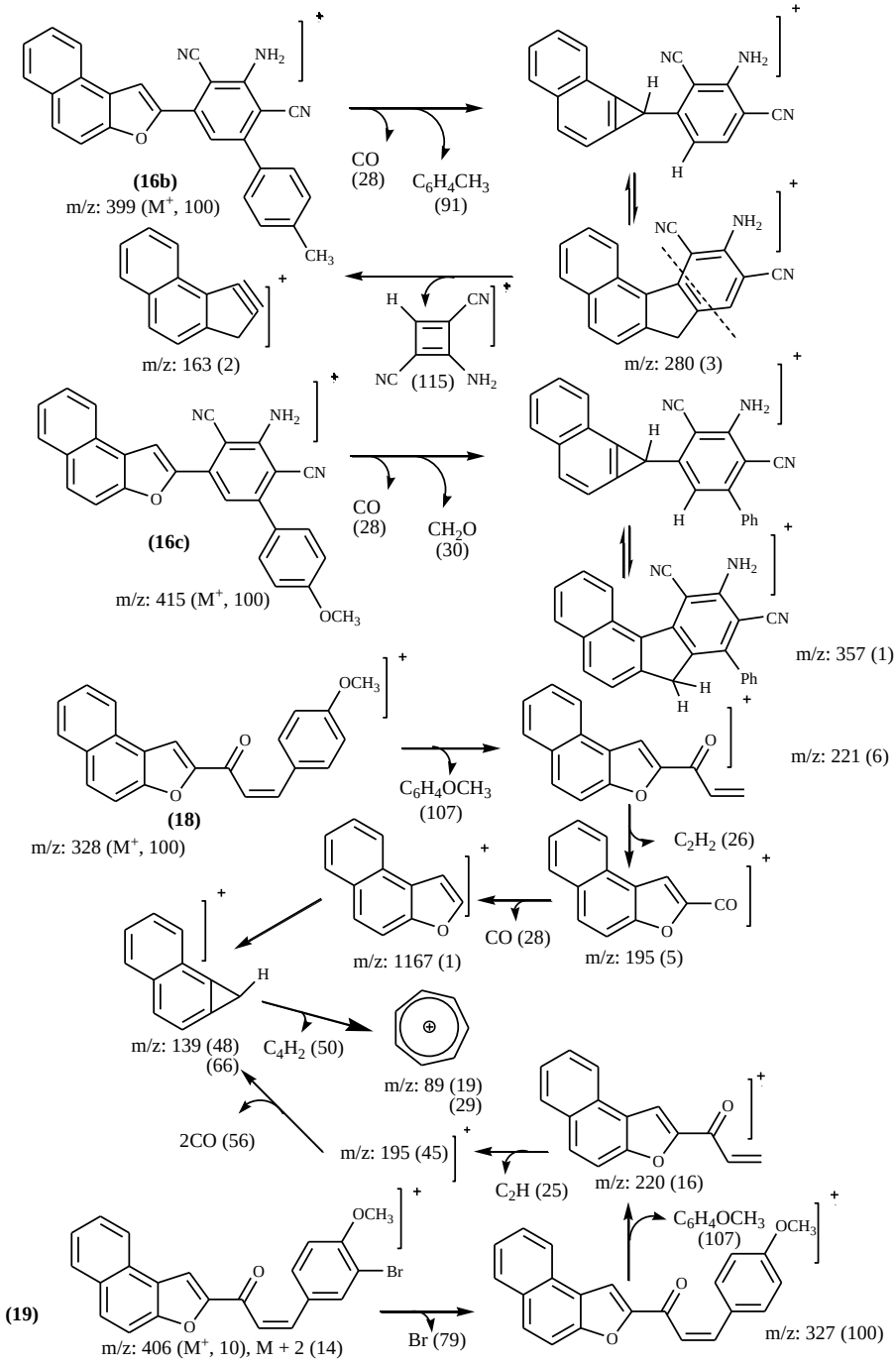
The mass spectrum of **3, 8b, 9** and **11** showed molecular ion peaks m/z; 210 (M^+, 32 %), m/z; 362 (M^+, 62 %), m/z; 332 (M^+, 49 %) and m/z; 318 (M^+, 100 %) respectively, while the mass spectrum of **16b,c, 18, 19, 20a,b, 21** and **22**, showed molecular ion peaks m/z; 399 (M^+, 100), m/z; 415 (M^+, 100), m/z; 328 (M^+, 100), m/z; 406 (M^+, 10), m/z; 342 (M^+, 100), m/z; 418 (M^+, 100), and m/z; 408 (M^+, 100) respectively.

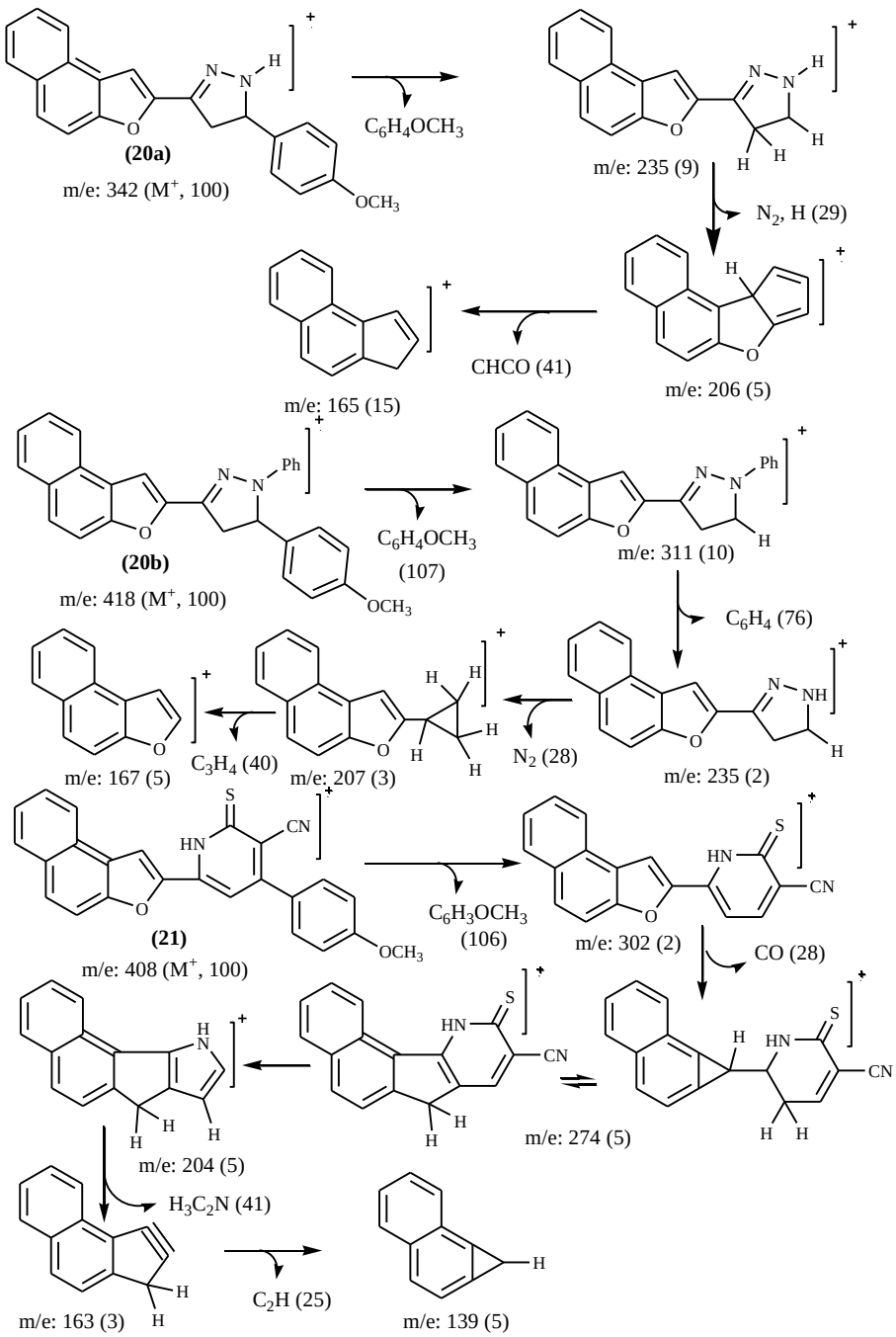
The fragmentation pattern of compounds **3, 8b, 9** and **11** are illustrated in (Chart 1), while the fragmentation pattern of compounds **16b,c, 18, 19, 20a,b** and **21** are illustrated in (Chart 2).

The studies of the mass spectroscopic fragmentation reflect the stability of the ring systems with molecular ion in many derivatives being the base peak


(3)
m/z: 210 (M+, 32)
CH2 = C = O
(42)
m/z: 168 (3)
CO, H (29)
m/z: 139 (100)
(8b)
m/z: 362 (M+, 62)
N2 (28)
m/z: 334 (31)
2
m/z: 88 (100)
2C2H2
(26)
CO, H (29)
CN (26)
51 (70)
m/z: 257 (26)
(9)
m/z: 332 (M+, 48)
CH2 = C = O
(42)
m/z: 290 (100)
(15)
(11)
m/z: 318 (M+, 100)
CO (28)

(Chart 1)


(16b)
m/z: 399 (M+, 100)
CO (28)
C6H4CH3 (91)
m/z: 163 (2)
(115)
m/z: 280 (3)
(16c)
m/z: 415 (M+, 100)
CO (28)
CH2O (30)
m/z: 357 (1)
(18)
m/z: 328 (M+, 100)
C6H4OCH3 (107)
m/z: 221 (6)
C2H2 (26)
CO (28)
m/z: 1167 (1)
m/z: 195 (5)
m/z: 139 (48)
C4H2 (50)
m/z: 89 (19)
(29)
(66)
2CO (56)
m/z: 195 (45)
C2H (25)
m/z: 220 (16)
(19)
m/z: 406 (M+, 10), M + 2 (14)
Br (79)
C6H4OCH3 (107)
m/z: 327 (100)


(20a)
m/e: 342 (M+, 100)
C6H4OCH3
m/e: 235 (9)
N2, H (29)
m/e: 206 (5)
CHCO (41)
m/e: 165 (15)
(20b)
m/e: 418 (M+, 100)
C6H4OCH3
(107)
m/e: 311 (10)
C6H4 (76)
m/e: 235 (2)
N2 (28)
m/e: 207 (3)
C3H4 (40)
m/e: 167 (5)
(21)
m/e: 408 (M+, 100)
C6H3OCH3
(106)
m/e: 302 (2)
CO (28)
m/e: 274 (5)
m/e: 204 (5)
H3C2N (41)
C2H (25)
m/e: 163 (3)
m/e: 139 (5)

(Chart 2)

Table III. Spectral data of the newly prepared compounds.

Cpd. No	IR (v,cm^{-1})	^{1}H NMR, ^{13}C NMR (δ, ppm) / MS
3	1666 (CO)	8.59-7.70 (m, 6H, Ar-H), 7.89 (s, 1H, H-3), 2.62 (s, 3H, Me), 187.19 (CO), 153.36 (C-9a), 151.90 (C-2), 130.11 (C-3a), 129.90 (C-8), 128.98 (C-7), 127.85 (C-7a), 127.52 (C-6), 125.60 (C-5), 123.64 (C-4), 122.61 (C-3b), 113.69 (C-3), 112.74 (C-9), 26.33 (Me), m / z 210 (M^+, 32), 168 (3), 139 (100), 113 (11), 89 (15), 63 (38).
4	2225(CN), 1567 (C=C)	8.22-7.59 (m, 6H, Ar-H), 7.92 (s, 1H, H-3), 2.71 (s, 3H, Me).
6	3459,3346 (NH),1601 (C=N).	8.17-6.92 (m, 12H, Ar-H+NH), 7.70 (s, 1H, H-3), 2.35 (s, 3H, Me), 154.81 (C-9a), 151.72 (C=N), 145.45 (C-2), 132.94 (C-1`), 130.01 (C-3a), 128.94 (C-8), 128.66 (C-3`,5`), 127.06 (C-7a), 126.44 (C-7), 125.28 (C-6), 124.75 (C-5), 123.97 (C-3b), 123.65 (C-4), 119.39 (C-4`), 113.04 (C-3), 112.22 (C-9), 102.89 (C-2`,6`), 12.80 (Me).
7	3420, 3312, 3198 (NH_2), 2205 (CN)	8.15-7.54 (m, 6H, Ar-H), 7.50 (s, 1H, H-3), 7.47 (s, 1H, H-2`), 6.87 (br, 2H, $NH_2$), 166.73 (C-2), 151.10 (C-9a), 149.68 (C-4`), 130.08 (C-2`), 128.75 (C-7), 127.35 (C-7a), 127.03 (C-3a), 120.69 (C-4), 125.8 (C-5), 124.89 (C-6), 123.47 (C-3b), 123.44 (C-2`), 116.37 (CN), 111.97 (C-8), 105.87 (C-3), 100.97 (C-9), 80.58 (C-3`)
8b	2226 (CN)	8.69 (s, 1H, CH=C), 8.41-7.48 (m, 12H, Ar-H + CH furan), 4.41 (s, 1H, CH-CN), m / z 362 (M^+, 62), 334 (31), 257 (26), 228 (9), 200 (24), 168 (13), 139 (66), 138 (35), 129 (75), 90 (20), 89 (12), 88 (100), 51 (70)
9	3262, 3210 (NH), 2228 (CN), 1704 (CO)	8.83 (br, 1H, NH), 8.59-7.25 (m, 6H, Ar-H), 7.37 (s, 1H, H-3), 7.32 (s, 1H, H-2`), 2.36 (s, 3H, Me), m / z 332 (M^+; 48), 290 (100), 234 (3), 202 (5), 176 (2), 149 (2), 98 (2).
11	3178 (bonded OH and/or NH), 2216 (CN), 1692 (CO)	m / z 318 (M^+, 100), 290 (15), 261 (9), 233 (5), 163 (9), 145 (8), 104 (2), 63 (3).

16a	3470, 3350, 3234 (NH_2), 2216 (CN)	8.36- 7.49 (m, 12H, Ar-H), 7.25 (s, 1H, H-3), 6.81 (brs, 2H, NH_2).
16b	3475, 3345, 3238 (NH_2), 2221 (CN);	8.44-7.35 (m, 11H, Ar-H), 7.32 (s, 1H, H-3), 6.85 (brs, 2H, NH_2), 2.41 (s, 3H, Me), 154.58 (C-9a), 152.44 (C-3`), 150.21 (C-2), 149.99 (C-5`), 139.31 (C-1`), 136.05 (C-4``), 134.49 (C-1``), 130.10 (C-3a), 129.27 (C-3``,5``), 128.91 (C-7), 128.37 (C-4), 127.85 (C-2``,6``), 127.22 (C-7a), 127.07 (C-5), 125.37 (C-6), 123.50 (C-8), 123.43 (C-3b), 116.10 (CN), 116.01 (CN), 115.22 (C-9), 112.21 (C-6`), 108.01 (C-3), 94.13 (C-2`), 89.52 (C-4`), 20.85 (Me). m / z 399 (M^+; 100), 280 (3), 163 (2), 97 (8).
16c	3470, 3348, 3236 (NH_2), 2218 (CN);	8.40-7.10 (m, 11H, Ar-H), 7.29 (s, 1H, H-3), 6.77 (brs, 2H, NH_2), 3.85 (s, 3H, OMe), m / z 415 (M^+, 100), 357 (1), 251 (1), 166 (1), 126 (1), 88 (1), 65 (1).
18	1674 (CO)	8.66-6.81 (m, 11H, Ar-H+CH-furan), 3.62, 3.16 (dd, 2H, CH=CH, J = 16.5 Hz), 3.61 (s, 3H, OMe), 177.76 (CO), 161.57 (C-4`), 153.71 (C-9a), 153.18 (C-2), 143.17 (CH), 130.78 (C-8), 130.16 (C-3a), 129.97 (C-7), 129.08 (C-2`,6`), 127.86 (C-7a), 127.62 (C-6), 127.08 (C-1`), 125.63 (C-5), 123.47 (C-4), 122.84 (C-3b), 119.45 (CH), 114.51 (C-3`,5`), 113.97 (C-3), 112.79 (C-9), 55.40 (OMe), m / z 328 (M^+, 100), 221 (6), 195 (5), 167 (1), 139 (48), 89 (19)
19	1685 (CO)	8.26-6.95 (m, 10H, Ar-H+CH-furan), 5.93, 5.69 (dd, 2H, CH =CH; J = 11.4 Hz), 3.85 (s, 3H, OMe), m / z 406 (M^+, 10), 408 (M^++2, 14), 327 (100), 220 (16), 195 (45), 139 (66), 89 (29).
20a	3410 (NH), 1610 (C=N)	m / z 342 (M^+; 100), 235 (9), 206 (5), 165 (15), 121 (39), 77 (22),
20b	1600 (C=N)	m / z 418 (M^+; 100), 311 (10), 235 (2), 207 (3), 167 (5), 145 (26), 91 (95)
21	3321(NH), 1308(C=S), 1596 (C=N);	m / z 384 (M^+; 87), 79 (2), 251 (2), 191 (6), 163 (14), 77 (6).
22	3405(NH), 2214(CN), 1596(C=C), 1298 (C=S);	m / z 408 (M^+; 100), 302 (2), 274 (2), 204 (5), 163 (3), 139 (5), 55 (2).

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