Action of Nitrogen and Carbon Nucleophiles on Benzoxazin-4(H)-one Derivative as Convenient Methods for the Synthesis of Some Novel Heterocyclic Systems

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Abstract— A novel heterocyclic compounds such as N-substituted quinazolin-4(H)-one, 1-H-pyridazino[6,1-b]-, [1,2]oxazino-[3,2-b]-, benzimidazolo[1,2-c], [1,2,4]-triazolo[2,3-c]quinazoline derivatives, [1,3,4]-thiadiazole, [1,2,4]triazoles derivatives were obtained via the reaction of 2-[(1Z, 3E)-1-benzamido-4-phenyl-1,3-butadien-1-yl]-6,8-dibromo-[3,1]-benzoxazin-4(H)-one **4** with a variety of nitrogen and carbon nucleophiles and carbon electrophiles, the starting group carry a substituent in position-2 which increase both the stability and the reactivity of [3,1]benzoxazin-4(H)-one nucleus.

Keywords— [1,2]oxazino-[3,2-b] quinazolinone, benzimidazolo[1,2-c]quinazoline, [1,2,4]-triazolo[2,3-c]quinazoline, [1,3,4]-thiadiazole, [1,2,4]triazoles.

INTRODUCTION

Nitrogen-containing heterocycles are present in a variety of biologically active compounds that can be used in a wide range of therapeutic areas. Quinazoline derivatives are an important class of nitrogen-containing heterocycles, which display a wide variety of biological activities, where they have a lot of medicinal applicability[1]-[7], such as antipyretic[8], antidepressant (CNS)[9], antiplatelet[10] and their effectiveness against ADP and collagen induced platelet aggregation[11].

Thus, in continuation of an earlier work on quinazolin-4(3H)-ones[12]-[15] and as a part of an effort to offer a useful framework for the purpose of synthesis of pharmacologically active compounds[16]-[17], it was interesting to prepare the title compound 2-[(1Z,3E)-1-benzamido-4-phenyl-1,3-butadien-1-yl]-6,8-dibromo-4H[e]benzo[3,1]oxazin-4-one **(4)** to be used as a key starting material to synthesize a new category of fused quinazolin-10(H)-one derivatives. Thus, treatment of 3,5-dibromoanthranilic acid **(1)** with the Δ^2-oxazol-5-one derivative **2** in acetic acid yielded 2-acylamino-3,5-dibromobenzoic acid derivative **3** which cyclized via intramolecular cyclization[18] (Exo-trig cyclization) to give the desired [3,1]-benz-oxazin-4(H)-one derivative **4** which contains a conjugated bulk group moiety to increase both the stability and the reactivity towards nucelophiles[19] due to decreasing both the electron deficiency and the steric hindrance of the oxazinone nucleus [3,1]-benzoxazin-4(H)-one. the presence of dibromo substituent often provides high lipophilicity[19].

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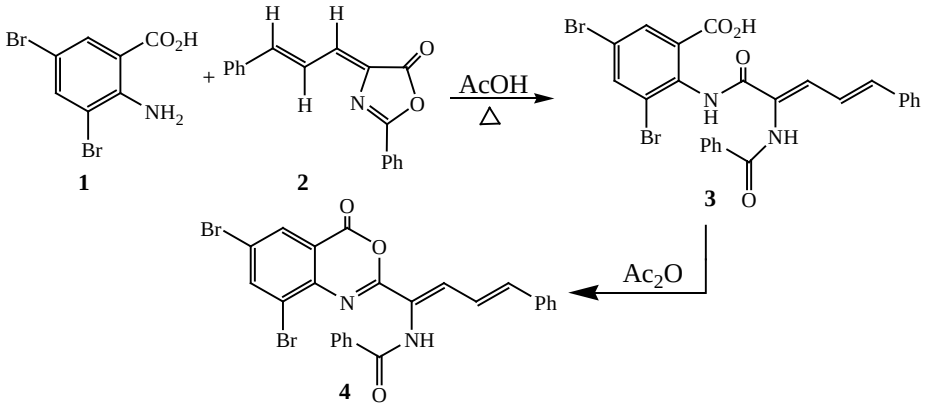
The structure of **4** is confirmed spectroscopically, where its IR showed the disappearance of $\upsilon_{C=O(acid)}$, υ_{OH}, ^{1}H-NMR deduced the absence of the exchangeable signal of OH (acid) beside the negative result for its acidity test (Scheme 1).

RESULTS AND DISCUSSION

As a part of our interest in heterocyclic chemistry [20]-[31] we have reported a simple and convenient approach for the synthesis of different heterocyclic compounds. Thus, reaction of **4** with heterocyclic primary amines namely furfuryl amine and/or 2-aminopyrimidine was studied. Thus, treatment of 4 with furfuryl amine (in ethanol at room temperature and/or in refluxing ethanol) gave the corresponding anilide derivative **5** and the cyclized product 2-[(1*Z*,3*E*)1-benzamido-4-phenyl-1,3-butadien-1-yl]-6,8-dibromo-3-((furan-2-yl)methyl)-quinazolin-4(*H*)-one **6a**, respectively. Also, **5a** was cyclized to **6a** by heating with anhydrous $ZnCl_2$. However, compound **4** did not react with 2-aminopyridine either in ethanol at room temperature or in refluxing ethanol. On the other hand, when compound **4** was heated with 2-aminopyridine in an oil bath (at 130-140^{0}C) the cyclic product **6b** was formed.

Furthermore, when **4** was allowed to react with hydrazine hydrate (98%), the product was depending upon the reaction conditions, where in boiling ethanol it afforded the hydrazide derivative **7a [32],[33]**, while in boiling n-butanol the corresponding 1-H-pyridazino[6,1-b]quinazoline-10(H)-one derivative **8a** was achieved. Compound **8a** was also obtained by heating **7a** in an isomental at 135-140^{o}C.

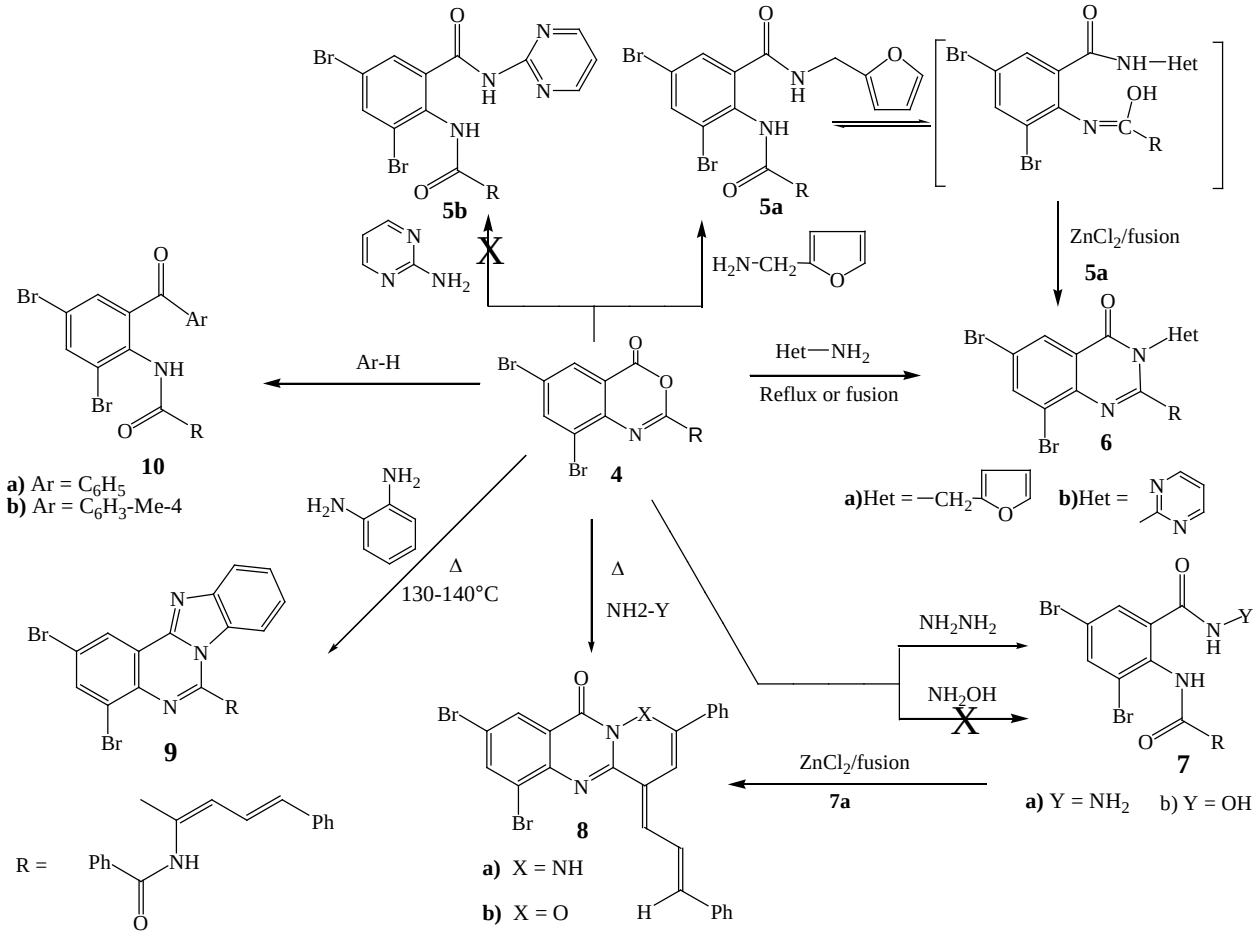


Scheme 1

It was found that $NH_2OH.HCl/CH_3COONa$ in refluxing ethanol did not react with **4**, but when the same reaction was carried out in refluxing dry pyridine the corresponding [1,2]oxazino-[3,2-*b*]quinazoline-10(*H*)one **8b** was formed.

The study was extended to the action of *o*-phenylene diamine on **4** by heating in an oil bath at 130-140^{o}C which afforded benzimidazolo-[1,2-c]quinazoline derivative **9**.

It has been reported that [3,1]-benzoxazin-4(H)ones can be considered as semi acid anhydrides and they undergo many reactions of true acid anhydrides[34]. Thus, the interaction of **4** with aromatic hydrocarbons such as benzene and/or toluene in the presence of anhydrous $AlCl_3$ (99%) afforded 2-[1-benzamido-1-oxo-4-phenyl-1,3-butadien-1-yl] aminoaroylphenones[35] **10a,b**, respectively (Scheme 2).



Scheme 2

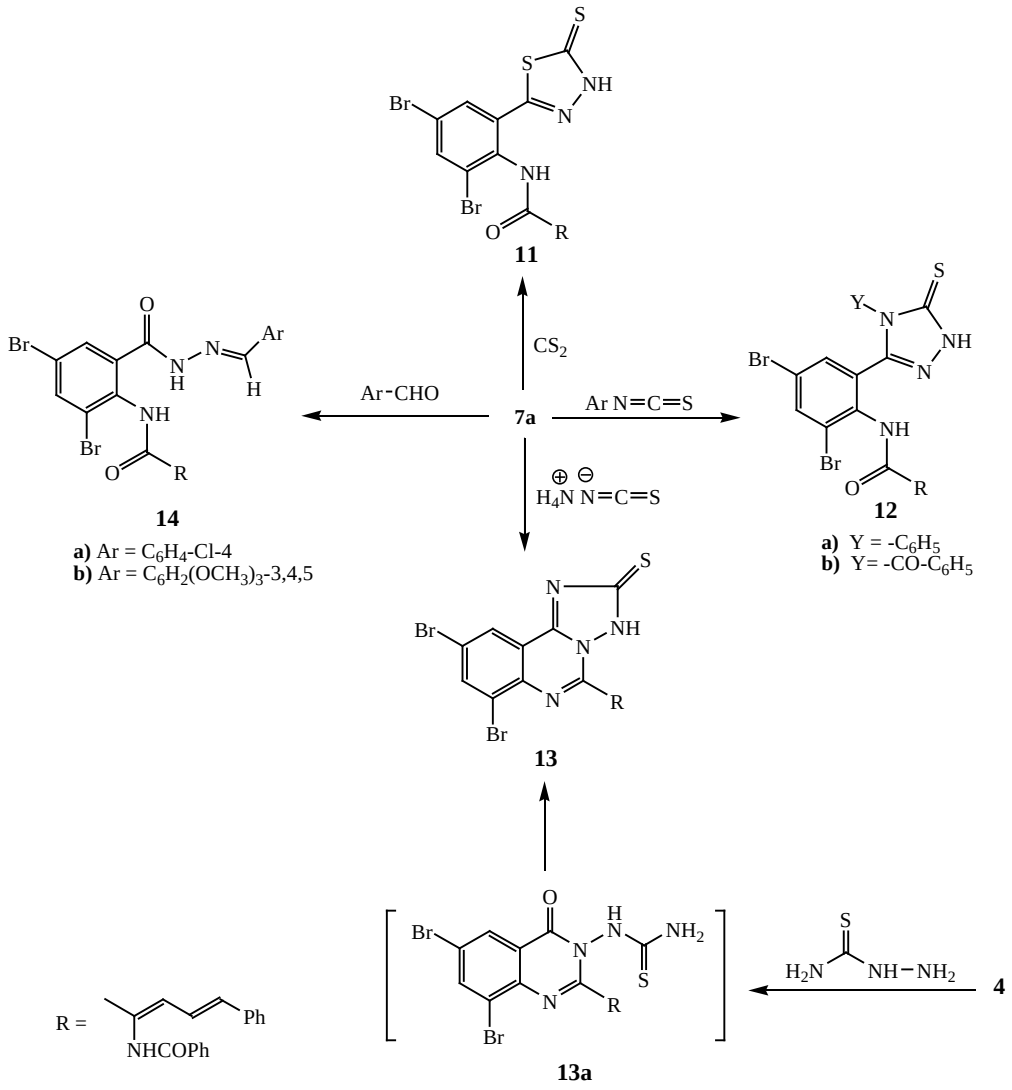
The acid hydrazide **7a** used as a starting material for synthesis of some novel heterocyclic compounds. Thus, when **7a** was allowed to react with carbon disulphide, aryl isothiocyanate (97%) namely phenyl and/or benzoyl isothiocyanate, it yielded 1,3,4-thiazole and 1,2,4-triazole derivatives, **11 and 12a,b** respectively.

The was interesting to study the reaction of **7a** with ammonium isothiocyanate (98%) which furnished 5-thioxo-[1,2,4]-triazolo[2,3-c]quinazoline derivative **13**.

On the other hand, the reaction of **4** with thiosemicarbazide (99%) yielded **13** as a sole product via the predicted intermediate **13a**.

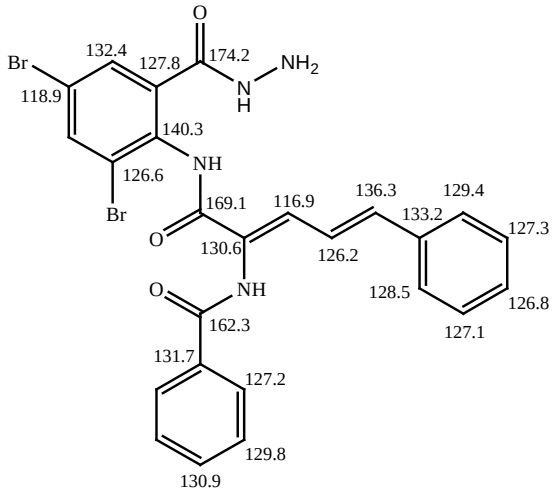
Treatment of **7a** with aromatic aldehydes, namely, p-chlorobenzaldehyde and/or 3,4,5-trimethoxybenzaldehyde afforded the products **14a**,**b**, respectively[15][36].

The IR and ^{1}H-NMR of the synthesized heterocycles **11-13** showed the absence of the broad bands and signals of NH_2 group of **7a**. (Scheme 3).

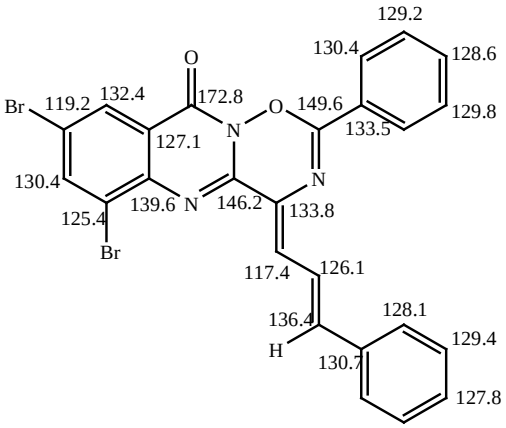


Scheme 3

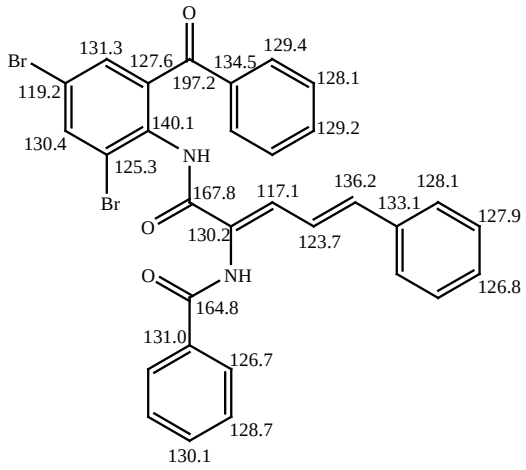
The structure of the newly synthesized products **4-14** are well established via their elemental analysis and various spectroscopic techniques including IR, ^{1}H-NMR, ^{13}C-NMR and mass[37]-[42] spectral data. **(c.f. Chart.1 and Tables.1,2)**



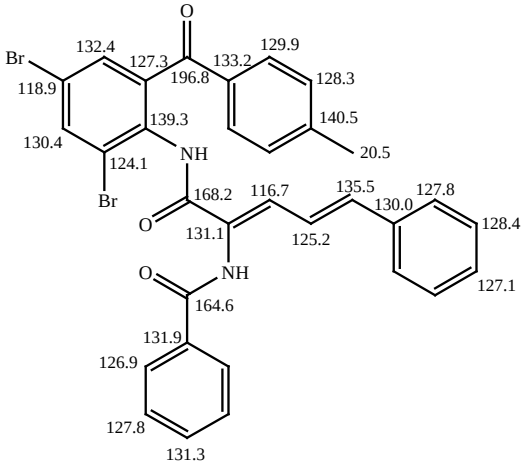
Compound 7a (DMSO-d_6)



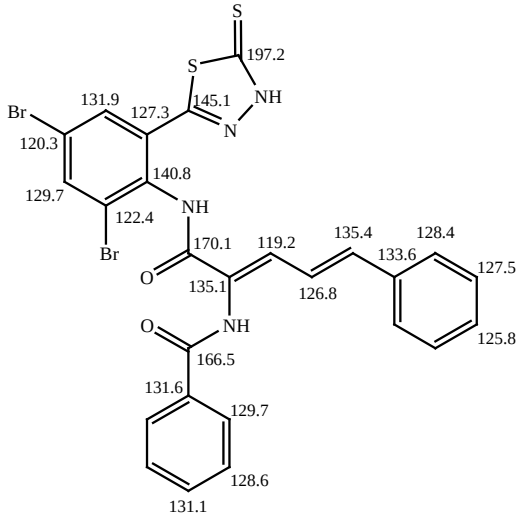
Compound 8b ($CDCl_3$



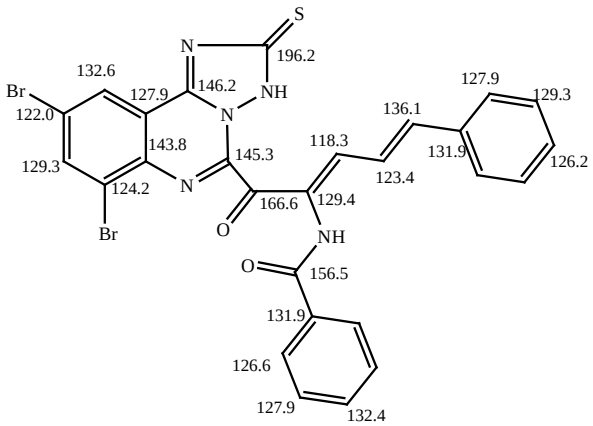
Compound 10a ($CDCl_3$)



Compound 10b(DMSO-d_6)



Compound 11 (DMSO-d_6)



Compound 13 (DMSO-d_6)

Chart 1. ^{13}C-NMR data in δ-values

EXPERIMENTAL:

All the research fine chemicals are from Alf Aesar (A Johnson Matthey Company). All melting points were taken on Griffin and Geory melting point apparatus and are uncorrected. IR spectra were recorded on Pye Unicam SP 1200 spectrophotometer using KBr Wafer technique. ^{1}H-NMR was determined on a Bruker-AC-400 spectrometer operating at 400 MHz for ^{1}H-NMR and 100 MHz for ^{13}C-NMR using TMS as internal standard (chemical shifts δ , are reported in parts per million (ppm) and coupling constant *J* are in Hz). EI-MS were measured on a Schimadzu-GC-MS instrument operating at 70 eV. elemental analyses were carried at the microanalytical unit, Faculty of science, Ain shams University by using Perkin-Elmer 2400 C, H, N elemental analyzer and satisfactory analytical data (± 0.3) were obtained for all compounds. The homogeneity of the synthesized compounds were controlled by TLC. Reagents and solvents were used from commercial sources without purification.

3,5-Dibromo-2-[(1Z,3E)-1-benzamido-1-oxo-4-phenyl-1,3-butadien-1-yl]aminobenzoic acid (3)

A mixture of 3,5-dibromoanthranilic acid **1** (2.95 g, 0.01 mole) and 4-cinnamylidene-2-phenyl-Δ^2-oxazol-5-one **2** (2.75 g, 0.01 mole) in acetic acid (20 ml) was refluxed for 6 hr until no more substrate. The reaction mixture was concentrated to half its volume using the rotatory evaporator and the solid that separated out after cooling then filtered off, washed several times with water, dried and recrystallized from a mixture of benzene-methanol (1 : 1) to give **3**.

2-[(1Z,3E)-1-benzamido-4-phenyl-1,3-butadien-1-yl]-6,8-dibromo-[3,1]-benzoxazin-4(H) one (4).

A mixture of **3** (5.7 g, 0.01 mole) and freshly distilled acetic anhydride (15 ml) was heated gently with stirring on hot plate for 0.5 hr. The reaction mixture was left over night at room temperature then triturated several times with light petroleum ether (b.p. 60-80°C). The crude solid was collected by filtration, and treated with water several times, washed with cold 5% sodium carbonate solution (30 ml) to remove the unreacted acid then washed with water several time then filtered off, dried to give **4**.

Reaction of 4 with furfuryl amine; Formation of 2-N[(2Z,4E)-2-benzamido-1-oxo-5-phenyl penta-2,4-dien-1-yl]-3,5-dibromo-N-(furan-2-methyl)benzamide(5a)

A solution of **4** (1.66 g, 0.003 mole) and furfuryl amine (99%) (0.5 ml, 0.005 mole) in ethanol (20 ml) was stirred at room temperature for 30 min. and then refluxed for 1 hr. The reaction was followed up. The solid that deposited after cooling was filtered off, washed with ethanol to afford **5a.**

Ring closure of 5; Formation of 2-[1Z,3E)-1-benzamido-4-phenyl-1,3-butadien-1-yl]-6,8-dibromo-3-((furan-2-yl)methyl)quinazolin-4(H)-one (6a)

Method A:

A solution of **4** (1.66 gm, 0.003 mole) and furfuryl amine (99%) (0.5 ml, 0.005 mole) in ethanol (30 ml) was refluxed on water bath for 2 hr. A pale yellow solid was deposited after cooling to the room temperature then the reaction mixture was heated under reflux for another 3 hr with stirring, excess ethanol was evaporated under vaccum to its half volume, leave to cool at room temperature, the brown solid that separated out was filtered off, dried to afford **6a**.

Method B:

A mixture of **5** (1.95 gm, 0.003 mole) and anhydrous $ZnCl_2$ (4.1 gm, 0.03 mole) was mixed together well then heated in an isomantel at 130-140C for 3 hr. The reaction mixture was leave to cool then warmed water (50 ml) was added with stirring at room temperature for 30 min., a brown solid that yielded out was filtered off, washed several times with hot water, dried to afford **6a**.

Formation of 2-[1Z,3E)-1-benzamido-4-phenyl-1,3-butadien-1-yl]-6,8-dibromo-3-(pyrimidin-2-yl)quinazolin-4(H)-one (6b)

A mixture of **4** (5.52 gm, 0.01 mole) and 2-amino pyrimidine (98%) (1.46 gm, 0.015 mole) was heated in an oil-bath at 130-140°C for 4 hr (TLC). The cooled reaction mixture was triturated with aqueous methanol (2:8 v/v) and the deposited solid was filtered off, dried to give **6b**.

Action of hydrazine hydrate on 4; Formation of the hydrazide (7a)

A mixture of **4** (5.52 gm, 0.01 mole) and hydrazine hydrate (98%) (1.5 ml, 0.03 mole) in absolute ethanol (30 ml) was refluxed with stirring for 4 hr. Cooling to room temperature a colourless solid product was deposited which filtered off, dried to afford the hydrazide **7a**.

Formation of (Z)-6,8-dibromo-2-phenyl-4-[(E)-3-phenyl allylidene]-1H-[1,2,4]-triazino-[6,1-b] quinazoline-10(4H)one (8a)

Method A:

To a stirred solution of **4** (5.52 gm, 0.01 mole) in n-butanol (20 ml), hydrazine hydrate (98%) (1.5 ml, 0.03 mole) was added and the mixture was refluxed with stirring for 20 hr. The excess solvent was removed under vaccum. The residual was triturated with ethanol to yield **8a**.

Method B: (Authentic Methode): Converation of 7a to 8a

A mixture of **7a** (2.7 gm, 0.005 mole) and anhydrous $ZnCl_2$ (2.0 gm) was mixed well, then heated to be melted using a regulated isomental at 135-140°C for 2 hr, then the reaction mixture was poured onto ice/H_2O, the solid residue was filtered off, washed several times with hot water, dried, to yield **8a** which was identified via m.p, mixed m.p, TLC and IR comparison.

Action of hydroxyl amine on 4; Formation of (Z)-6,8-dibromo-2-phenyl-4-[(E)-3-phenyl allylidene]-[1,2,5]-oxadiazino[3,2-b] quinazoline-10(4H)one (8b)

To a stirred solution of **4** (5.52 gm, 0.01 mole) in dry pyridine (40 ml), hydroxyl amine hydrochloride (97%) (2.9 gm, 0.04 mole) was added in one portion. The mixture was heated under reflux with stirring for 16 hr. The cooled mixture was

acidified with cold dilute hydrochloric acid (20 ml, 2N). The solid that deposited out was collected by suction, washed several times with water, and dried to afford **8b**.

Reaction of 4 with o-phenylene diamine; Formation of benzimidazolo-[1,2-c]quinazoline derivative (9)

A mixture of the benzoxazinone **4** (5.52 gm, 0.01 mole) and *o*-phenylene diamine (1.63 gm, 0.015 mole) was mixed well then heated on oil-bath to be melted. Heating was continued for another 6 hr at 130-140°C. the crude product was triturated with water, filtered off, washed with ether, to give **9**.

Reaction of 4 with aromatic hydrocarbons; Formation of N-((1Z,3E)-1-(2,4-dibromo-6-(substituted)phenylcarbamoyl)-4-phenylbuta-1,3-dienyl)benzamide (10a,b)

A solution of **4** (5.52 gm, 0.01 mole) in dry benzene and/or toluene (80 ml) was added gradually to a cold suspension of granulated anhydrous aluminum chloride (99%) (5.4 gm, 0.04 mole) benzene and/or toluene (50 ml). The temperature of the mixture was not allowed to rise above 60°C. The suspension mixture was stirred for additional 12 hr and left overnight then poured into ice-cold hydrochloric acid (150 ml, 2N). The solid that deposited was filtered off, washed with water several times, dried to afford **10a,b**, respectively.

Reaction of the acid hydrazide 7a with CS_2/ KOH; Formation of N-((1Z,3E)-1-(2,4-dibromo-6-(4,5-dihydro-5-thioxo-1,3,4-thiadiazol-2-yl)phenylcarbamoyl)-4-phenylbuta-1,3-dienyl)benzamide (11)

To a mixture of the acid hydrazide **7a** (5.4 gm, 0.01 mole), potassium hydroxide (2 g in 5 ml H_2O) in ethanol (50 ml), carbon disulphide (5 ml) was added dropwise with stirring at room temperature for 30 min. The whole mixture was refluxed with stirring for 12 hr. The solvent was removed using rotatory evaporator and the residue was acidified with cold hydrochloric acid (15 ml, 2N). The crude solid was collected by filtration, dried to afford **11**.

Reaction of the acid hydrazide 7a with phenylisothiocyanate; Formation of N-((1Z,3E)-1-(2,4-dibromo-6-(4,5-dihydro-4-phenyl-5-thioxo-1H-1,2,4-triazol-3-yl)phenylcarbamoyl)-4-phenylbuta-1,3-dienyl)benzamide (12a)

To a solution of **7a** (5.4 gm, 0.01 mole) in dry pyridine (50 ml), phenyliso-thiocyanate (97%) (1.3 ml, 0.01 mole) was added dropwise during stirring at room temperature for 30 min. and the whole mixture was refluxed with continuous stirring for 3 hr. Evaporation of solvent to its half volume using rotatroy evaporator was carried out, a semisolid product which triturated with light petroleum ether (b.p. 60-80°C) to give **12a**.

Reaction of 8 with benzoylisothiocyanate; Formation of N-((1Z,3E)-1-(2,4-dibromo-6-(4,5-dihydro-4-benzoyl-5-thioxo-1H-1,2,4-triazol-3-yl)phenylcarbamoyl)-4-phenylbuta-1,3-dienyl)benzamide (12b).

A mixture of **7a** (5.4 gm, 0.01 mole), benzoylisothiocyanate (98%) (1.4 ml, 0.01 mole) in dry THF (30 ml) was refluxed with stirring for 6 hr. The reaction mixture was poured on cold water (80 ml) and extracted with ether. The ethereal layer washed several times with water, dried over anhydrous Na_2SO_4. Evaporation under vaccum was carried out till the semisolid product was achieved then triturated with aqueous methanol (1 : 5) to afford **12b**.

Formation of 5-[(1Z,3E)-1-benzamido-4-phenyl-buta-1,3-dien-1-yl]-7,9-dibromo-2-thioxo-2,3-dihydro[1,2,4] triazolo[1,5-c]quinazoline (13)

Method A:

A mixture of **7a** (5.4 gm, 0.01 mole) and ammoniumisothiocyanate (98%) (2.2 ml, 0.03 mole) was fused on an oil-bath at 180°C for 30 min. The solid that formed was dissolved in hot water (30 ml) and then acidified with dil cold hydrochloric acid (20 ml, 2N). The solid formed was filtered off, dried to yield **13**.

Method B:

A solution of **4** (5.4 gm, 0.01 mole) and thiosemicarbazide (99%) (1.7 gm, 0.015 mole) in n-butanol (30 ml) was refluxed with stirring for 12 hr. The solid that deposited after concentration and cooling was filtered off, dried to give **13** (identify m.p, mix. M.p, TLC and IR spectrum comparison).

Reaction of 7a with aromatic aldehydes; Formation of 2-N-[(2Z, 4E)-2-benzamido-1-oxo-5-phenyl-penta-2,4-dien-1-yl]amino-3,5-dibromo-N-(E)-(arylidene) benzoic acid hydrazide (14a,b)

A mixture of **7a** (5.4 gm, 0.01 mole) and aromatic aldehydes namely p-chloro benzaldehyde and/or 3,4,5-trimethoxybenzaldehyde (0.01 mole) was refluxed in ethanol (80 ml) with stirring for 3 hr. After evaporation to its half volume and cooling, the solid that deposited out was collected by suction, dried to yield **14a,b** respectively.

CONCLUSION:

In this paper, the synthesized 2-[(1*Z*,3*E*)-1-benzamido-4-phenyl-1,3-butadien-1-yl]-6,8-dibromo-[3,1]-benzoxazin-4(H) one (**4**) was successfully converted to quinazoline and quinazolinone drivatives. Also, a variety of hetrocyclic compounds were synthesized such as triazole and thiadiazole. The structure of the newly synthesized compounds were elucidated by different spectroscopic tools.

Table .1 Physical characterizations of compounds (3-14).

Compd No.	Colour m.p°C	Solvent of cryst Yield %	M.F M.wt	Analysis Calcd/Form				
				%C	%H	%N	%Br	%S
3	Yellow (205-07)	B/M (66)	$C_{25}H_{18}N_2O_4Br_2$ (570.24)	52.66 52.73	3.18 3.26	4.91 5.13	28.02 27.98	- -
4	Orange (120-22)	L.P (54)	$C_{25}H_{16}N_2O_3Br_2$ (552.22)	54.38 54.58	2.92 3.06	5.07 4.99	28.94 28.81	- -
5a	Pale yellow (215-17)	B (78)	$C_{30}H_{23}N_3O_4Br_2$ (649.34)	55.49 55.53	3.57 3.62	6.47 6.66	24.61 24.83	- -
6a	Pale brown (127-29)	A (31)	$C_{30}H_{21}N_3O_3Br_2$ (631.32)	57.08 57.30	3.35 3.30	6.66 6.30	25.31 25.08	- -
6b	Brown (201-03)	M (14.6)	$C_{29}H_{19}N_5O_2Br_2$ (629.31)	55.35 55.10	3.04 2.92	11.13 10.98	25.39 25.62	- -
7a	Colourless (165-66)	B (86)	$C_{25}H_{20}N_4O_3Br_2$ (584.27)	51.39 51.47	3.45 3.29	9.59 9.24	27.35 27.84	- -
8a	Yellow (188-89)	E (28)	$C_{25}H_{16}N_4OBr_2$ (548.24)	54.77 54.38	2.94 2.86	10.32 10.13	29.15 29.22	- -
8b	Pale yellow (211-13)	M (36)	$C_{25}H_{15}N_3O_2Br_2$ (549.22)	54.67 54.46	2.75 2.88	7.65 7.99	29.10 28.96	- -
9	Brown (219-21)	E/B 31.5	$C_{31}H_{20}N_4OBr_2$ (624.33)	59.64 59.38	3.23 3.28	8.97 9.02	25.60 25.48	- -
10a	Light brown (186-88)	L.P (48)	$C_{31}H_{22}N_2O_3Br_2$ (630.34)	59.07 58.93	3.52 3.39	4.44 4.71	25.35 25.97	- -
10b	Pale brown (231-32)	E (33.2)	$C_{32}H_{24}N_2O_3Br_2$ (644.36)	59.65 60.18	3.75 4.13	4.35 4.47	24.08 24.31	- -
11	Yellow (303-05)	T (18)	$C_{26}H_{18}N_4O_2S_2Br_2$ (642.39)	48.61 48.23	2.82 2.76	8.72 9.06	24.88 25.05	9.98 10.02
12a	Yellow (143-45)	E (27)	$C_{32}H_{23}N_5O_2SBr_2$ (701.44)	54.79 54.63	3.31 3.17	9.98 9.76	22.78 22.94	4.57 4.91
12b	Pale brown (228-30)	AM (23)	$C_{33}H_{23}N_5O_3SBr_2$ (729.45)	54.34 54.66	3.18 3.42	9.60 9.86	21.91 22.12	4.40 4.31
13	Pale brown (233-35)	B (34.6)	$C_{26}H_{17}N_5O_5Br_2$ (607.33)	51.42 50.96	2.82 3.00	11.53 11.84	26.40 26.61	5.28 5.42
14a	Brown (196-98)	E (50)	$C_{32}H_{23}N_4O_{13}ClBr_2$ (706.82)	54.38 54.91	3.28 3.06	7.93 7.65	22.61 22.93	Cl 5.02 5.22
14b	Orange (230-31)	E (48.2)	$C_{35}H_{30}N_4O_6Br_2$ (762.46)	55.14 54.95	3.97 4.11	7.35 7.82	20.96 21.08	- -

A = Acetic acid B = Benzene E = Ethanol
M = Methanol AM = Aqueous Methanol (1:5, v/v) T = Toluene
B/M = Benzene-Methanol mixture (1:1, v/v) L.P = Light petrol 100-120°C E/B = Ethanol-benzene mixture (1:1, v/v)

Table II. Spectroscopic data of new compounds (3-14)

Compd No.	IR (ν in cm^{-1})					^{1}H-NMR (δ in ppm)	EI-MZ m/z (abundance %)
	$\nu_{OH/NH}$ $-NH_2$	$\nu_{C=O}$	$\nu_{C=N}$	$\nu_{C=C}$	$\nu_{C=S}$ -S-		
3	(br) 3486	1712 (acid) 1667 (anilide)	1626	1612	——	11.2 (s, 1H, exchangeable with D_2O, COOH), 9.2 (br.s, 2H, exchangeable with D_2O, 2-NH), 8.6-7.5 (m, $12H_{arom.}$), 7.2-6.35 (3d, 3H, AMX olefinic protons, J_{AM} = 8 Hz, J_{AX} = 6 Hz, J_{MX} = 14 Hz).	[M] 570 (23.6), [M+2] 572 (21.1), m/e 526 (30.2), 410 (70.3), 394 (36.3), 390 (63.7), 372 (48.3), 305 (100, as BP), 294 (16.3), 276 (55.2), 212 (27.4), 145 (69.4), 105 (66.4) and 77 (42.3).
4	3290	1780 (δ-lact) 1703 (amide)	1630	1615	——	9.1 (s, 1H, exchangeable with D_2O, -NH), 8.3-7.5 (m, $12H_{arom.}$), 7.3-6.6 (3d, 3H, olefinic H's, J_{AM} = 6 Hz, J_{AX} = 5 Hz, J_{MX} = 16 Hz).	[M] 552 (23.6), [M+2] 554 (11.8), m/e 510 (30.2), 394 (70.3), 372 (100, as BP), 350 (29.4), 290 (18.7), 275 (21.6), 249 (22.8), 248 (14.2), 200 (33.1), 147 (72.4), 143 (15.3), 131 (64.8), 118 (16.3), 105 (79.8), 103 (12.2), 77 (49.6), 67 (36.8), and 51 (24.3). (c.f. Chart 1)
5a	3320	1674 (amide) 1658 (anilide)	1622	1614	——	————————	————————
6a	3328	1743 (Quinz) 1672 (amide)	1628	1605	——	————————	[M] 631 (14.6), [M+2] 633 (12.3), m/e 527 (27.4), 451 (41.8), 437 (27.8), 410 (44.3), 393 (13.6), 383 (100,BP), 363 (22), 248 (23.1), 225 (32.4), 144 (19.8), 131 (63.7), 118 (12.7), 105 (93.8), 96 (61), 77 (71.4), and 65 (54.2). (c.f. Chart 2)
6b	3291	1727 (Quinz) 1668 (amide)	1626	1595	——	9.1 (s, 3H, exchangeable with D_2O, NH), 8.3-7.6 (m, $15H_{arom.}$), 7.4-6.3 (3d, 3H, olefinic H's, J_{AM} = 6 Hz, J_{AX} = 5 Hz, J_{MX} = 16 Hz).	[M] 629 (5.8), [M+2] 631 (4.6), m/e 525 (23.1), 471 (5.6), 444 (52.3), 435 (32.4), 408 (41.8), 393 (13.6), 381 (100,BP), 363 (22.0), 248 (23.1), 223 (22.1), 144 (19.8), 131 (63.7), 118 (12.7), 105 (93.8), 94 (43.7), 77 (71.4), and 65 (54.2). (c.f. Chart 2)
7a	3580 3350 3270 3174	1689 (hydraz) 1674 (amide) 1656 (anilide)	1624	1616	——	9.3 (br.s, 1H, exchangeable with D_2O, -NH), 8.6 (br.s, 2H, exchangeable with D_2O, -2NH), 7.8-7.1 (m, $12H_{arom.}$), 7.0-6.4 (3d, 3H, AMX olefinic protons, J_{AM} = 8 Hz, J_{AX} = 6 Hz, J_{MX} = 14 Hz), 4.4 (br.s, 2H, exchangeable with D_2O, $-NH_2$).	[M] 584 (17.6), [M+2] 586 (13.7), m/e 471 (35.2), 424 (72.8), 404 (23.5), 393 (23.7), 373 (43.8), 363 (32.4), 334 (100, as BP), 316 (51.8), 309 (30.1), 248 (18.9), 146 (22.7), 118 (29.3), 105 (82.7) and 77 (63.6).

8a	3216	1722 (Quinz)	1625	1605	——	8.3 (br.s, 1H, exchangeable with D_2O, NH), 7.7-7.0 (m, $12H_{arom.}$), 6.9-6.3 (3d, 3H, olefinic H's, J_{AM} = 6 Hz, J_{AX} = 5 Hz, J_{MX} = 16 Hz).	[M] 548 (9.8), [M+2] 550 (5.1), m/e 390 (13.1), 333 (100, as BP), 330 (64.4), 300 (27.8), 287 (25.8), 286 (48.4), 273 (22.4), 259 (82.0), 233 (23.4), 230 (18.3), 171 (17.6), 159 (23.3), 146 (43.1), 131 (28.6), 105 (77.4), and 65 (11.8). (c.f. Chart 4)
8b	——	1742 (Quinz)	1625	1615	ν_{N-O} 980	8.4-7.5 (m, $12H_{arom.}$), 7.4-6.6 (3d, 3H, olefinic H's, J_{AM} = 6 Hz, J_{AX} = 5 Hz, J_{MX} = 16 Hz).	[M] 473 (3.1), [M+2] 475 (2.9), m/e 333 (14.4), 315 (11.2), 287 (25.8), 225 (43.1), 212 (16.8), 211 (63.8), 198 (18.7), 184 (100,BP), 171 (17.6), 159 (23.3), 157 (26.8), 147 (43.1), 131 (28.6), 105 (77.4) and 65 (11.8). (c.f. Chart 4)
9	3420	1641	1622	1606	——	8.9 (br.s, 1H exchangeable with D_2O, -NH), 8.3-7.6 (m, 16 $H_{arom.}$), 7.3-6.8 (3d, 3H, AMX, olefinic proton, J_{AM} = 8 Hz, J_{AX} = 6 Hz, J_{MX} = 13 Hz).	[M] 624 (17.4), [M+2] 626 (31.8), m/e 520 (34.6), 466, (39.4), 429 (53.1), 403 (38.7), 375 (51.6), 364 (26.9), 350 (13.6), 260 (17.8), 246 (15.7), 244 (14.6), 219 (100,BP), 144 (32.4), 116 (41.9), 105 (73.8), 90 (39.2), 77 (83.8), and 65 (26.4). (c.f. Chart 5)
10a	3340 3267	1692 (aroyl) 1685 (amide) 1654 (anilide)	1623	1610	——	9.3 (s, 1H, exchangeable with D_2O, -NH), 8.6 (s, 1H, exchangeable with D_2O, -NH), 8.4-7.4 (m, $17H_{arom.}$), 7.2-6.7 (3d, 3H, AMX olefinic protons, J_{AM} = 8 Hz, J_{AX} = 6 Hz, J_{MX} = 14 Hz).	[M] 630 (21.9), [M+2] 632 (13.2), 626 (31.8), 509 (19.3), 472 (7.6), 368 (18.1), 365 (39.4), 351 (27.6), 278 (33.1),263(20.6), 249 (22.8), 248 (14.2), 236 (17.9), 225 (72.4), 144 (53.8), 131 (64.8), 119 (12.2), 118 (16.3), 105 (100), 77 (49.6), 67 (36.8) and 51 (24.3).
10b	3409 3286	1686 (aroyl) 1677 (amide) 1657 (anilide)	1625	1616	——	9.52 (s, 1H, exchangeable with D_2O, -NH), 8.8 (s, 1H, exchangeable with D_2O, -NH), 8.3-7.3 (m, $16H_{arom.}$), 7.19-6.6 (3d, 3H, AMX olefinic protons, J_{AM} = 8 Hz, J_{AX} = 6 Hz, J_{MX} = 14 Hz), 2.34 (s, 3H, Ar-CH_3-4).	——————
11	3312 3226	1676 (amide) 1655 (anilide)	1618	1609	1092 (C=S) 1355 (C-S-C) 925 (-SH)	11.1 (br.s, 1H, exchangeable with D_2O, NH-C=S), 9.3 (br.s, 1H, exchangeable with D_2O, 1-NH), 8.0 (br, s, 1H exchangeable with D_2O, NH of thiadiazole), 7.9-7.3 (m, $12H_{arom.}$), 7.2-6.6 (3d, 3H, olefinic H's, J_{AM} = 6 Hz, J_{AX} = 5 Hz, J_{MX} = 16 Hz),.	[M] 642 (0), [M+2] 644 (0.0), m/e 484 (28.1), 441 (91.9), 408 (43.8), 395 (32.4), 380 (38.2), 379 (23.8), 363 (11.4), 304 (33.1), 289 (52.6), 276 (28.9), 273 (84.6), 263 (19.7), 261 (13.9), 250 (41.4), 247 (26.1), 223 (62.8), 208 (29.6), 182 (19.3), 147 (8.6), 143 (14.6), 123 (26.7), 117 (34.8), 105 (100,BP), 104 (21.6), 91 (31.7), 77 (38.4), and 65 (17.3). (c.f. Chart 3)

12a	3328 3273	1681 (amide) 1662 (anilide)	1623	1609	1086 (C=S) 938 (-SH)	9.2 (s, 2H, exchangeable with D_2O, -NH diazole), 8.9 (br.s, 1H, exchangeable with D_2O, NH, thiadiazole), 8.3-7.6 (m, $17H_{arom.}$), 7.4-6.6 (3d, 3H, olefinic H's, J_{AM} = 6 Hz, J_{AX} = 5 Hz, J_{MX} = 16 Hz).	[M] 729 (0.0), [M+2] 731 (0.0), m/e 569 (26.), 416 (21.8), 399 (13.2), 332 (100, as BP), 172 (42.8), 147 (19.8), 105 (81.4) and 77 (31.7).
12b	3370 3266	1701 (aroyl) 1673 (amide) 1665 (anilide)	1630	1610	1071 (C=S) 915 (SH)	9.4 (br.s, 2H, exchangeable with D_2O, 2 HN-C=O), 8.9 (br.s, 1H, exchangeable with D_2O, -NH, thiadiazole), 8.7-7.6 (m, $17H_{arom.}$), 7.5-6.7 (3d, 3H, olefinic H's, J_{AM} = 6 Hz, J_{AX} = 5 Hz, J_{MX} = 16 Hz).	[M] 729 (0.0), [M+2] 431 (0), m/e 569 (17.8), 528 (77.3), 464 (29.4), 448 (17.3), 408 (43.8), 395 (32.4), 389 (39.6), 374 (38.3), 348 (22.4), 335 (48.2), 334 (32.8), 308 (52.6), 295 (37.4), 273 (84.6), 269 (17.6), 263 (19.7), 210 (11.9), 147 (18.6), 143 (14.6), 117 (18.6), 105 (100,BP), 104 (21.6), 91 (31.7), 77 (38.4), and 65 (17.3). (c.f. Chart 3)
13	3342 3274	1683 (amide) 1658 (anilide)	1628	1605	1093 (C=S) 922 (-SH)	9.1 (br.s, 1H, exchangeable with D_2O, -NHC=O), 8.4 (br.s, 1H exchangeable with D_2O, NH of thiadiazole), 8.3-7.6 (m, $12H_{arom.}$), 7.4-6.6 (3d, 3H, olefinic H's, J_{AM} = 6 Hz, J_{AX} = 5 Hz, J_{MX} = 16 Hz).	———
14a	3346 3295 3168	1683 (hydraz.) 1670 (amide) 1656 (anilide)	1625	1612	———	9.78 (s, 1H, exchangeable with D_2O, NH-N), 8.9 (br.s, 2H, exchangeable with D_2O, 2NH-C=O), 8.6 (s, 1H, -N=CH-Ar, -N=CH-Ar), 8.4-7.4 (m, $16H_{arom.}$), 7.3-6.5 (3d, 3H, AMX olefinic protons, J_{AM} = 8 Hz, J_{AX} = 6 Hz, J_{MX} = 14 Hz).	———
14b	3392 3266 3173	1682 (hydraz.) 1628 (amide) 1658 (anilide)	1628	1610	———	9.9 (s, 1H, exchangeable with D_2O, -NH-N), 8.7 (br.s, 2H, exchangeable with D_2O, 2NH-C=O), 8.3 (s, 1H, -N=CH-Ar)), 8.1-7.6 (m, $14H_{arom.}$), 7.4-6.6 (3d, 3H, AMX olefinic protons, J_{AM} = 8 Hz, J_{AX} = 6 Hz, J_{MX} = 14 Hz), 3.92 (s, 6H, 2 CH_3-O), 3.81 (s, 3H, CH_3-O).	[M] 762 (14.3), [M+2] 764 (12.8), m/e 602 (26.7), 582 (32.9), 415 (41.8), 388 (61.3), 320 (100, as BP), 160 (52.6), 105 (78.4) and 77 (61.1).

Solvent for NMR:
DMSO-d_6 for compounds: 3, 4, 6b, 7a, 8a, 11, 12b, 13, and 14a,b
$CDCl_3$ for compounds: 12a, 8b and 9

References:

[1] V. Bavetsias, E. Henderson, E McDonald;" Cyclopenta-[*g*]quinazolinone-based inhibitors of thymidylate synthase targeting α-folate receptor overexpressing tumours: synthetic approaches to 4-{*N*-[(6*RS*)-2-hydroxymethyl-4-oxo-3,4,7,8-tetrahydro-6*H*-cyclopenta[*g*]quinazolin-6-yl]-*N*-(prop-2-ynyl)amino}benzoic acid" Tetrahedron, 2007, 63(7), 1537.

[2] G. Grover, S. Kini; " Synthesis and evaluation of new quinazolone derivatives of nalidixic acid as potential antibacterial and antifungal agents" European J. Med. Chem. 2006, 41(2), 256.

[3] C. Sheng-Li, F. Yu-Ping, J. Yu-Yang, L. Shi-Ying, D. Guo-Yu, L. Run-Tao; "Synthesis and in vitro antitumor activity of 4(3*H*)-quinazolinone derivatives with dithiocarbamate side chains" Bio. Med. Chem. Lett., 2005, 15(7), 1915.

[4] S. Chavan, R. Sivappa, "A facile total synthesis of rutaecarpine" Tetrahedron Lett. 2004, 45(5), 997.

[5] S. Kumar Das, V. Krovvidi, H. Jagadheshan, J. Iqbal, "Synthetic studies of *cis*-4-Amino-L-proline derivatives as novel lipid lowering agents" Bio. Med. Chem. Lett. 2002, 12(24**)**, 3579.

[6] M. R. Mahmoud,.E .A. El-Bordany, N.F.H. Mahmoud, F.M.S. El-Azm; " New 2,3-disubstituted quinazolin-4(3H)-ones from 2-undecyl-3,1-benz-oxazin-4-one" J. Chem. Res. 2007, 9 ,541.

[7] Á. Kiss, J. Kökösi, R. Rotter, I. Hermecz, "Synthesis of 8-Substituted 7-Azarutaecarpines" Tetrahedron, 2000, 56 (40**)**, 7987.

[8] G Daidone, B Maggio, D Raffa, S Plescia, ML Bajardi, A Caruso, VMC Cutuli, M Amico-Roxas, "Synthesis and pharmacological study of ethyl 1-methyl-5-[2-substituted-4-oxo-3(4*H*)-quinazolinyl]-1*H*-pyrazole-4-acetates", Eur. J. Med. Chem. 1994, 29 (9**)**, 707.

[9] M. Julino, M.F.G. Stevens, " Antitumour polycyclic acridines. Part 5.1 Synthesis of 7H-pyrido[4,3,2-kl]acridines with exploitable functionality in the pyridine ring" J. chem.Soc. Perk.Trans.1, 1998, 10, 1677.

[10] J. Morris, D. Wishka, A. Lin, W. Humphery, A. Wiltse, R. Gammill, T. Judge, S. Bisaha, N. Olds, "Synthesis and biological evaluation of antiplatelet 2-aminochromones" J. Med. Chem., 1993, 36, 2026.

[11] a) S. Kucukguzel, S. Rollas, H. Erdeniz, A. Kiranz, M. Ekinci, A. Vidin, "Synthesis, characterization and pharmacological properties of some 4-arylhydrazono-2-pyrazoline-5-one derivatives obtained from heterocyclic amines" Eur. J. Med. Chem. 2000, 35(7-8), 761. b) K. Pritchard, J. Al Rawi, C. Bradley, "Synthesis, identification and antiplatelet evaluation of 2-morpholino substituted benzoxazines" Eur. J. Med. Chem. 2007, 42(9), 1200.

[12] E.A. Soliman, M.A. Hassan, M.A.I. Salem, I.S. Sharif, "Synthesis of some new benzoxazone and quinazolone derivatives", J. Chem. Soc. Pak. 1984, 6(3), 183.

[13] M.A.I. Salem, E.A. Soliman, "Synthesis of some new 2-[2-(p-chlorobenzoyl)vinyl]-4H-3,1-quinazolin-4-one derivaties", Egypt. J. Chem. 1984, 27(6), 779.

[14] E.A. Soliman, M.A. Hassan, M.A.I. Salem, I.S. Sherif; "Some reactions od pyrazolinyl benzoxazones and quinazolones", J. Chem. Soc. Pak. 1986, 8(2), 97.

[15] H.M.F. Madkour, M.A.I. Salem, T.M. Abdel-Rahman, M.E Azab, "Reactions of 5-(p-anisyl)-2-methyl-7-(p-tolyl)-4H-pyrido-[2,3-d][1,3]-oxazin-4-one". Heterocycles. 1994, 38(1), 57.

[16] M. E Azab, E. A. Kassab, M. A. El-Hashash and R.S. Ali, "Synthesis and Antibacterial Activity of Some New 4(3H)Quinazolin-4-one Derivatives", Phosphorus, Sulfur and Silicon, 2009, 184, 610.

[17] a) M.R. Mahmoud, E.A. El-Bordany, M.E. Azab, E.A. Soliman, "Synthesis of new thiadiazoles, 1,2,4-triazolo[3,4-b]-1,3,4-thiadiazoles, 1,2,4-triazolo[2,3-c]quinazoline derivatives from 3,1-benzoxazin(4H)-one derivatives", J. Phosphrous, Sulfur and Silicon. 2007, 181, 1275. b) Maher A. El-Hashash, Mohammad E. Azab and Jehan M.Morsy "A Novel Series of Biologically Active Quinazolinones through Ring Transformation of 2-(5-Nitrofuran-2-yl)-4H-benzo[d][1,3]oxazin-4-one", International Journal of Scientific & Engineering Research, 2013, 4(12), 218.

[18] T.L. Gilchrist. Heterocyclic Chemistry, PITMAN Publishing LTD, London 1st Edit. 1985, 55.

[19] a) A.M.F. Oliveira, A.M. Salaheldin, M. Rodrigues, "Synthesis of some novel pyrazolo[3,4-*d*]pyrimidine derivatives" Arkivoc 2007, (XVI), 92. b) M. A. Mc Clinton, D.A. Mc Clinton, "Trifluoromethylations and related reactions in organic chemistry", Tetrahedron. 1992, 48, 6555.

[20] M.A.I. Salem, E.A. Soliman, M.B. Smith, M.R. Mahmoud, M.E. Azab, "Utility of 1-(2,4-dimethoxyphenyl)-3-aryl-prop-2-ene-1-ones as ring transformer in preparing heterocyclic compounds and their potential biological activities ", J. Phosphrous, Sulfur and Silicon, 2004, 179, 61.

[21] H.M.F. Madkour, M.A.I. Salem, M.I. Marzouk, M.E. Azab, N.F.H. Mahmoud, "Utility of cyanothioacetamide in the synthesis of pyrazolo[4,3-c], isoxazolo[4,5-c], thieno[2,3-b] and furo[3,2-c] of thioxopyridine derivatives and their antibacterial activities", Amm. Eurass. J. Sci. Res., 2007, 2(2), 161.

[22] M.A.I. Salem, H.M.F. Madkour, E.A. Soliman and N.F.H. Mahmoud, "Synthesis of bactericides via carbon nucleophiles on 1-(2,4-dimethoxyphenyl)-3-arylprop-2-ene-1-ones as Michael acceptors", Heterocycles, 2000, 53(5), 1129.

[23] H.M.F. Madkour, M.A.I. Salem, E.A. Soliman and N.F.H. Mahmoud, "A facil one-pot synthesis and antibacterial activity of aziridines and thiazines from 1,3-diarylprop-2-enones", Phosphorous, Sulfur and Silicon, 2001, 170, 15.

[24] W.M. Abdu, Y.O. El-Khoshnieh, M.A.I. Salem and R.F. Barghash, "A comparison of phosphonium and phosphonate carbanion reagents in reaction with 1,3-diphenyl-2-(hydroxyimino)-1,3-propanedione", Synlett, 2002, 9,.1417

[25] W.M. Abdu, M.A.I. Salem and A.A. Sediek, "Synthesis of spiro and fused five membered N-heterocycles from alkylidene phosphorane", Monatshefte für Chemie, 2003, 134, 1373.
[26] W.M. Abdu, M.A.I. Salem and R. Barghash, "The reaction of triphenylphosphine alkylene with 3(2-thienyl)acrylonitriles", J. Phosphorous, Sulfur and Silicon. 2003, 178, 125.
[27] W.M. Abdu, M.A.I. Salem and A.A. Sediek, "Cyclic oxyphosphoranes in the synthesis:A novel synthesis of oxathiaphospholenes, fused pyrimidines and aminooxyphosphoranes",. Arkivoc, 2005, XIV, 102.
[28] W.M. Abdu, M.A.I. Salem and R.F. Barghash. Arkivoc, "A facil access to condenced and spirosubstituted pyrimidiens phosphour ester", 2007, XIV, 45.
[29] M.A.I. Salem, H.M.F. Madkour, M.I. Marzouk, M.E. Azab and N.F.H. Mahmoud, "Pyrimidinthiones part 1: Utility of 2-thioxopyrimidin-6-(1H)ones as ring transformer in synthesis of fused bi- and tri-cyclic heterocyclic compounds and their potential biological activities", Phosphorous, Sulfur and Silicon, 2008, 183, 2596.
[30] F.C. Gaenzler, C.L. Guo, Y-W. Zhang, M.E. Azab, M.A.I. Salem, D.P. Fan and M.B. Smith, "2-Dienylphenacyloxazolones and an intramolecular Diels-Alder approach to A-B-C ring system of phenanthridone alkaloids", Tetrahydron, 2009, 65(43), 8781
[31] M.A.I. Salem, T.E. Ali and M.I. Marzouk, "Electron ionization mass spectra of organophosphorus compounds part I: The mass fragmentation pathway of cyclic α-amino-phosphonates monoester containing 1,2,4-triazinone moiety", Phosphorous, Sulfur and Silicon. 2012, 187(3), 336.
[32] A.Y. Soliman, M.A.I. Salem, E.A. Soliman, Y. Attia, A.M. Gaber, "Synthesis and Reactions of 2[α-(3,4-disubstitutedphenacyl)p-substitutedstyryl]-4H-3,1-benzoxazin-4-one", Chinese J. Chem., 1996, 14(5), 437.
[33] E.A. Soliman, H.M.F. Madkour, M.A.I. Salem, E.A. El-Bordainy, "Synthesis of some stable 4H-[3,1]-benzoxazin-4-ones and their behaviour towards nucleophiles", Bull. Polish Academy of Sciences, Chemistry. 1999, 47(3), 217.
[34] M.F. Ismail, N.A. Shams, M.R. Salem, S.A. Emara, " Reactions with 3,1-benzoxazin-4-ones. II. Behaviour of 6,8-dibromo-2-methyl-3,1-benzoxazin-4-one towards Friedel-Craft and Grignard reactions", J. Prakt. Chem., 1983, 325(3), 417.
[35] S.A. Essawy, M.A. El-Hashash, M.M. Mohamed, Ind. J. Chem., 1980, 19(B), 663.
36) W.M. Abdou, M.A.I. Salem, A.A. Sedik, "A convenient synthesis of 2H-1,4-benzoxazines, 3H-indol-3-ones and 2,3-dihydrobenzoxazoles", Bull. Chem. Soc. Jpn., 2002, 75, 1.
[37] K.M. Pritchard, J. Al-Rawi, C. Bradley, "Synthesis, identification and antiplatelet evaluation of 2-morpholino substituted benzoxazines", Euro J. of Med. Chem., 2007, 43(9**)**, 1200.
[38] M.V. Vovk, A.V. Bopbut, A.N. Chernega, "1-Aryl-1-chloro-2,2,2-trifluoroethyliso-cyanates, convenient reagents for synthesis of 2-aryl-2-trifluoromethyl-2,3-dihydro-4H-benzo-[e][1,3]oxazin-4-ones", J. Fluorine Chem., 2002, 116(2**)**, 97.
[39] I.M. El-Deen, M.E. El-Fattah, "Electron Impact Ionization Mass Spectra of 3-Substituted-2-hydroxy-4(3H)-quinazolinones", Bull Korean Chem. Soc. 2003, 24(4), 473.
[40] V.V. Ovcharenko, K. Pihlaja, G. Stajer, "Stereospecific fragmentations in the mass spectra of stereoisomeric isoindoloquinazolines", J. Amm. Soc. Mass Spectrum, 2003, 14(9**)**, 1049.
[41] T.J. Reddy, S. Prabhakar, U.V.R. Saradhi, V.J. Rao, M. Vairamani, "Mass spectral study on O,O-dialkyl N,N-dialkyl phosphoramidates under electron impact conditions", J. Amm. Soc. Mass Spectrum, 2004, 15(4**)**, 547.
[42] M.A.I. Salem, T.E. Ali, M.I. Marzouk and R.E. Khidre, "Electron ionization mass spectra of organophosphorus compounds part II: Mass spectrometric fragmentation of spiro(indene-2,3'-pyrazole)phosphonates, spiro(indene-2,3'-pyrazole)phosphanylidene, spiro(1,2,4-diaza-phosphole-3,2'-indenes) and (1,3-dioxo-2H-isoindolyl)phosphonate derivatives", Heteroatom Chem., 2012, 23(3), 254.