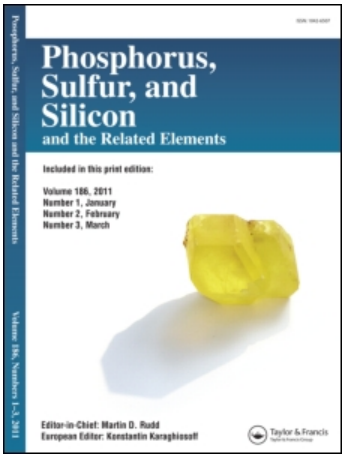

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SOME CYCLIZATION REACTIONS WITH 4-THIOHYDANTOIN: SYNTHESIS OF SOME NOVEL THIOPYRANOIMIDAZOLES, THIENOIMIDAZOLES AND IMIDAZOQUINOLINES AND SOME METAL COMPLEXES WITH BIOLOGICAL INTEREST

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SOME CYCLIZATION REACTIONS WITH 4-THIOHYDANTOIN: SYNTHESIS OF SOME NOVEL THIOPYRANOIMIDAZOLES, THIENOIMIDAZOLES AND IMIDAZOQUINOLINES AND SOME METAL COMPLEXES WITH BIOLOGICAL INTEREST

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4-Thiohydantoin **(II)** with chloroacetic acid, chloroacetanilides and cyanothioformamides gave thieno[2,3-d]imidazoles **(IV, V and IX)**, respectively. α,β-Unsaturated nitriles and anthranilic acids reacted with **(II)** to produce thiopyrano[2,3-d]imidazoles **(III)** and imidazo[4,5-b]quinolines **(VII)**. Some metal complexes were prepared and the antimicrobial activity of some selected compounds was also reported.

Keywords: Cyclization Reactions; Biological effects; metal complexes

INTRODUCTION

Cyanothioformamides[1,2] were used for the synthesis of polyfunctionalized heterocycles[3,4]. Thiohydantoin[5], thiopyran[6], thiophene[7] and quinoline[8] derivatives have been reported to exhibit biological activities. Our interest in activated nitriles[9] and cyanothioformamides[10–13] led us to carry some cyclization reactions with 4-thiohydantoin **(II)**.

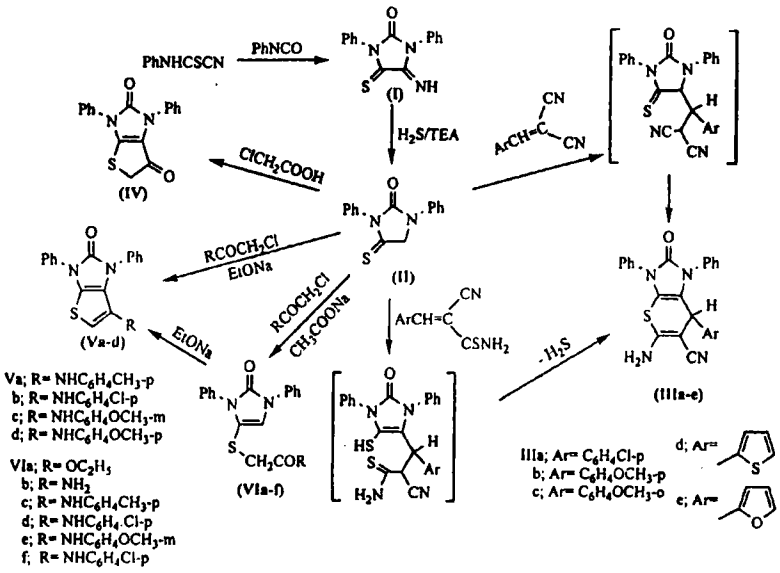
* Corresponding Author.

RESULTS AND DISCUSSION

Thus, cyanothioformanilide was reacted with phenyl isocyanate to give 5-imino-1,3-diphenyl-2-imidazolidinone-4-thione (**I**)[1] which on treatment with H_2S produced the thiohydantoin (**II**)[3]. The higher reactivity of (**II**) promote the authors to couple it with different reagents to produce various fused heterocycles with biological interest such as thiopyrano[2,3-d]imidazoles, thieno[2,3-d]imidazoles and imidazo[2,3-d]quinolines. Some of the synthesized products have been used as ligand in the preparation of cobalt and copper complexes. The biological activity of some of the synthesized products were tested against various bacteria.

Interaction of (**II**) with α,β-unsaturated nitriles in ethanol containing a few drops of piperidine furnished the corresponding thiopyrano[2,3-d]imidazoles (**IIIa-e**). On using arylidines of cyanothioacetamide to react with (**II**), H_2S was liberated and the same products (**III**) were obtained (m.p., m.m.p. and TLC) (if they have the same R group). These findings could be rationalized according to the mechanism illustrated in Scheme (1). Compounds (**III**) were characterized by IR, ^1H NMR and mass spectrum of (**IIIa**)which showed a peak at m/z 269 (15%) for the thiohydantoin and 188 (35%) for the arylidenemalononitrile fragments. Interaction of (**II**) with chloroacetic acid using ethanol as medium and sodium ethoxide as catalyst furnished the thieno[2,3-d]imidazole (**IV**)through alkylation followed by cyclodehydration. Formation of (**IV**) encouraged the authors to extent this reaction to include ethyl chloroacetate, chloroacetamide and chloroacetanilides. Attempted interaction of (**II**) with these reagents in EtOH/ AcONa was expected to produce thieno[2,3-d]imidazole structure (**V**), but instead alkylation took place to produce the anilides (**VI**). Repetation of this reaction using EtOH/EtONa caused cyclization and the required thieno[2,3-d]imidazoles (**V**) were obtained, Scheme (1). A strong evidence for structure (**V**) was arrived at from cyclization of (**VI**) using EtOH/ EtONa to produce (**V**)(m.p., m.m.p. and TLC). Compounds (**I-VI**) are illustrated at Scheme (1).

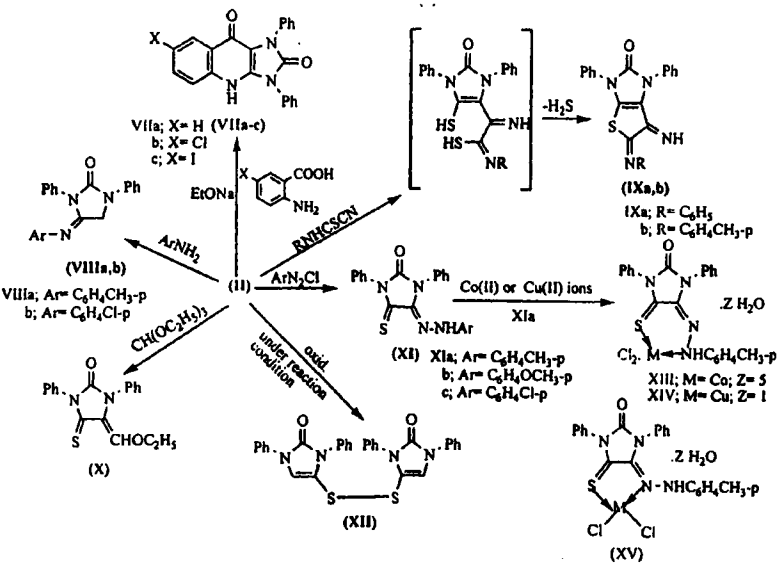
Anthranilic acid and its derivatives such as 5-chloro and 5-iodo were reacted successfully with thiohydantoin (**II**) through elimination of one mole of both H_2S and H_2O to produce imidazo[4,5-b]quinolines (**VII**). Aromatic amines were reacted successfully with (**II**) through elimination of H_2S to give 5-arylimino-1,3-diphenyl-2-imidazolidinones (**VIII**). Thiohydantoin (**II**) could be also reacted successfully with cyanothioforma-



SCHEME 1

mides in ether and in the presence of triethylamine as catalyst to furnish the thieno[2,3-d]imidazoles (**IX**). The mechanism of formation is illustrated in Scheme 2. Also, triethyl orthoformate was reacted with thiohydantoin (**II**) in refluxing acetic anhydride to yield 5-ethoxymethylidine-2-oxo-1,3-diphenyl-4-imidazolidinethione(**X**). Coupling of (**II**) with aryldiazonium chloride furnished 5-arylazo derivatives (**XI**). It is a point of interest to illustrate that almost in all the above reactions, the disulphide derivatives (**XII**) could be isolated which can be attributed to oxidation of (**II**) under the reaction conditions. Compounds (**VII-XII**) were given at Scheme (2).

Since, imidazolidine derivatives are potentially interesting, the authors selected (**XIa**) to react with Co(II) and Cu(II) ions to prepare metal complexes. Thus, interaction of the metal salt (1m mole) with the ligand (**XIa**) (1 m mole) in boiling ethanol furnished the corresponding complexes (**XIII** and **XIV**) respectively, Scheme (2). Their structures have been assigned by thermal analyses (TG & DTA), IR spectra and elemental analyses.



SCHEME 2

The structures **(XIII & XIV)** were favoured over **(XV)** due to the fact that the lone pair of p-toluidine nitrogen is more available than those of the imidazole imino nitrogen.

Thermal decomposition of Co(II)-5-(p-tolyl)azo-4-thiohydantoin complex (XIII)

The TG thermogram of Co(II)-5- arylazo-4-thiohydantoin complex exhibited multisteps weight loss. The first step in the range 50–140°C amounting to (14%) which is in accordance with the loss of five water molecules. The second step occur in the range 180–300°C the mass reach (26%) which is in accordance with the loss of two chlorine atoms. The final step in the range between 300–700°C a complete decomposition of the metal chelate occured to reach (88%) the remaining stable product is cobalt (II) oxide.

The DTA. curve showed sharp endothermic peak at 70°C which is probably due to the loss of water and is immediately followed by two endothermic peaks at 150–180°C which can be attributed to such a loss of two chlorine atom followed by an exothermic peak at 396°C.

Thermal decomposition of Cu(II)-5-(p-tolyl)azo-4-thiohydantoin complex (XIV)

TG thermogram of Cu(II)-5-arylazo-4-thiohydantoin complex displayed three weight loss steps, the first step in the range 130–170°C with weight loss amounting to (4%), in accordance with the loss of one water molecule. The second step in the range between 210–270°C represents the mass loss of 17% which is in accordance with the loss of two chlorine atoms. At temperatures between 330–650°C, a complete decomposition of parent molecule leaving metal oxide as stable end product.

Infrared Spectra of the Solid Complexes

The important IR bands of the free ligand and their Cu(II) and Co(II) complexes bands were recorded in Table (I).

TABLE I Relative IR bands of ligand and their metal chelat

Free Ligand	*Complex*		*Assignment*
	Cu(II); (XIV)	*Co(II), (XVIII)*	
1416	1420	1425	ν C=S
1600	1593	1592	ν N=N
	3445	3420	Stretching vibration (OH) of water molecules

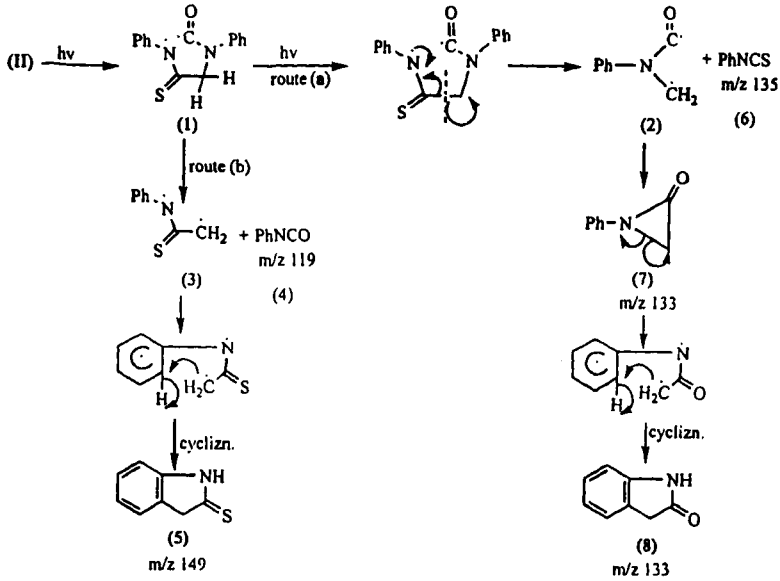
The ν C=S band appeared at 1416 cm^{-1} in the IR spectrum of free ligand. This band acquired a shift to higher frequencies of the resulting metal chelates. The ν N=N frequency of the band appeared at 1594 cm^{-1} and showed a very small shift in complex formation.

The new band appeared in the IR spectra of the Cu(II) and Co(II) complex at 3445 cm^{-1} and 3420 cm^{-1} respectively; can be assigned to stretching vibration OH group of water molecules.

Photolysis and Pyrolysis of 1,3-diphenyl-4-thiohydantoin (II)

Photolysis of 1,3-diphenyl-4-thiohydantoin **(II)** in acetone as a solvent at λ_{max} 320 nm for 10 hrs. afforded phenyl isocyanate, phenyl isothiocyanate, oxindole and 2-thioxoindole. Formation of these products implied

homolysis of (N-CO) bond to account for biradical (1) which with further decomposition (route a), rearranged to phenyl isothiocyanate m/z 135 (6) and biradical (2) which underwent intramolecular cyclization to α – lactam[14] (7) m/z 133. The most probable pathway for the formation of oxindole[15] (8) is through homolysis of (N-C) bond followed by intramolecular cyclization to oxindole[16] (8) m/z 133. Another competing pathway (route b) involves (N-C) bond fission and rearrange to phenyl isocyanate m/z 119 (4) and biradical (3) that underwent intramolecular cyclization and afforded 2-thioxoindole (5) under the reaction conditions. Pyrolysis of (II) in boiling tetralin for 8 hrs. gave the same products obtained in photolysis experiment Scheme (3).



SCHEME 3

ANTIBACTERIAL ACTIVITY

Some of the newly synthesized compounds were tested for their antibacterial activity against five species of bacteria namely; *Staphylococcus aureus* (NCTC 7447), *Bacillus subtilis* (NCTC 10400), *Sarcin* (ATCC 9341),

Escherichia coil (NCTC 10416) and *Kelebsiella pneumonia* (NCIMB 9111), using the agar diffusion method[17].

A 1 mg ml^{-1} solution in dimethyl formamide (DMF) was used. The bacteria was maintained on nurtient agar. DMF showed no inhibition zones. The agar media was inoculated with different microorganisms culture tested. After 24h of incubation at 30°C, the diameter of inhibition zone (mm) was measured (Table II). Ampicillin in a concentration 25 μg ml^{-1} was used as a reference for antibacterial activity. The results were represented in Table (II).

TABLE II Antibacterial[a] screening of the synthesized compounds:

Compd No.	*Staphylococcus aureus* (NCTC 7447)	*Bacillus subtilis* (NCTC 10400)	*Sarcin* (ATCC 9341)	*Escherichia coil* (NCTC 10416)	*Kelebsiella pneumonia* (NCIMB 9111)
IIIa	++	++	++	+++	++
IIIb	+++	+	+	++	+
IIIc	---	+++	++	+	+
IIId	+	+	+	+	+++
IIIe	++	+++	+	----	----
VIa	++	++	----	+	+
VIc	+	++	+	+++	++
VIe	+	+	+	++	++
VIf	+	+	+	+++	+++
XIa	+	++	++	++	++
XIb	++	+++	----	+	+
DMF	----	----	----	----	----

(-) Resistant, (+) moderately sensitive giving a zone of inhibition 11 mm. (++) sensitive giving a zone of inhibition 12 mm. (+++) very sensitive giving a zone of inhibition 13 mm.
a. Inhibition zones are measured in mm. The concentration used is $4x\ 10^{-5}$ M. Control discs were performed with DMF (dimethyl formamide) and no zone of inhibition were observed.

Most of the synthesized compounds were found to possess various antibacterial activity towards the microorganisms used with minimal inhibitory concentration (MIC). However of none of the tested compounds superior activity than the reference drug.

TABLE III IR spectra of the synthesised compounds prepared

Compd. No.	ν_{max}/cm^{-1}
IIIa	3420, 3170 (NH_2), 3035 (CH-arom.), 2969 (CH-aliph.), 2206 (C≡N), 1696 (C=O).
IIIb	3415, 3175 (NH_2), 3035 (CH-arom.), 2975 (CH-aliph.), 2205 (C≡N), 1727 (C=O).
IIIc	3435, 3185 (NH_2), 3040 (CH-arom.), 2950 (CH-aliph.), 2200 (C≡N), 1740 (C=O).
IIId	3410, 3175 (NH_2), 3035 (CH-arom.), 2960 (CH-aliph.), 2210 (C≡N), 1742 (C=O).
IIIe	3430, 3170 (NH_2), 3040 (CH-arom.), 2930 (CH-aliph.), 2205 (C≡N), 1742 (C=O).
IV	3060 (CH-arom.), 2925 (CH-aliph.), 1748, 1714 (C=O).
Va	3280 (NH), 1735 (C=O)
Vb	3320 (NH), 1730 (C=O)
Vc	3460 (NH), 1740 (C=O)
Vd	3365 (NH), 1730 (C=O)
VIa	1725 (C=O), 2950 (CH aliph.)
VIb	3325, 3310 (NH), 1739, 1668 (C=O)
Vic	3320 (NH), 1740, 1670 (C=O)
VId	3305 (NH), 1734, 1668 (C=O)
VIe	3330 (NH), 1742, 1669 (C=O)
VIf	3370 (NH), 1736, 1683 (C=O)
VIIa	3295 (NH), 1721 (C=O)
VIIb	3282 (NH), 1722 (C=O)
VIIc	3290 (NH), 1724 (C=O)
VIIIa	3060 (CH-arom.), 2880 (CH-aliph.), 1740 (C=O), 1640 (C=N).
VIIIb	1743 (CO) and 1645 (C=N).
IXa	3120 (NH), 1640 (C=N), 1740 (C=O)
IXb	3125 (NH), 2995 (CH aliph.), 1725 (CO), 1615 (C=N)
X	2920 (CH), 3060 (CH-arom.), 1704 (C=O), 1485 (amid II), 1312 (amid I).
XIa	3150 (NH), 1744 (C=O), 1600 (N=N)
XIb	3175 (NH), 1745 (C=O), 1654 (C=N), 1590 (N=N)
XIc	3145 (NH), 1746 (C=O), 1654 (C=N), 1580 (N=N)
XII	1715, 1712 (C=O), 1591, 1593 (C=C).

EXPERIMENTAL

Mps are uncorrected. Elemental analyses were carried out in the Micro-analytical Laboratories of the Faculty of Science, Cairo University. IR spectra (KBr) were measured on a Shimadzu IR 440 spectrophotometer. ^{1}H NMR spectra on a JEDL FX 90 Q (90 MHz) spectrophotometer and mass spectra on a Shimadzu GC-MS-QP 1000 EX spectrometer using a direct-inlet system.

Thiopyrano[2,3-d]imidazoles (IIIa-e)

Method (A)- A mixture of thiohydantoin (**II**; 0.01 mol), substituted cinnamonitriles (0.01 mol) and piperidine (0.5 mL) in absolute ethanol (30 ml) was refluxed 4h. The reaction mixture was then cooled, poured into crushed ice, neutralized with dil. HCl and the obtained product was recrystallized from the proper solvent to give **IIIa-e** (Table IV). Method (B)- A mixture of thiohydantoin (II; 0.01 mol), arylidine of cyanothioacetamide (0.01 mol) and piperidine (0.5 ml) in ethanol (30 ml) was refluxed 4h. The reaction mixture was then cooled, poured into crushed ice, neutralized with dil HCl and the obtained product was recrystallized from the appreciate solvent to give **IIIa-e** (Table IV).

TABLE IV Physical data of the synthesized compounds prepared

Compd. No.	*Yield (%)*	*M.P. (°C)*	*Cryst. solvent*	*Mol. Formula (Mol. wt)*	*Elemental analyses Required/Found, %*			
					C	*H*	*N*	*S*
IIIa	60	155	Benzene	$C_{25}H_{17}ClN_4OS$	65.72	3.72	12.27	7.01
				(456.50)	65.60	3.50	12.30	7.00
IIIb	67	145	Ethanol	$C_{26}H_{20}N_4O_2S$	69.03	4.42	12.39	7.08
				(452.00)	69.00	4.50	12.50	7.10
IIIc	70	135	Ethanol	$C_{26}H_{20}N_4O_2S$	69.03	4.42	12.39	7.08
				(452.00)	69.20	4.50	12.40	7.00
IIId	75	150	Ethanol	$C_{23}H_{16}N_4OS_2$	64.48	3.74	13.08	14.95
				(428.00)	64.50	3.60	13.20	15.10
IIIe	52	158	Ethanol	$C_{23}H_{16}N_4O_2S$	66.99	3.88	13.59	7.77

Compd. No.	*Yield (%)*	*M.P. (°C)*	*Cryst. solvent*	*Mol. Formula (Mol. wt)*	*Elemental analyses Required/Found, %*			
					C	*H*	*N*	*S*
				(412.00)	67.00	3.70	13.60	7.90
IV	75	110	Ethanol	$C_{17}H_{12}N_2O_2S$	66.23	3.90	9.09	10.39
				(308.00)	66.40	3.80	9.10	10.50
Va	60	260	Ethanol	$C_{24}H_{19}N_3OS$	77 54	4.78	10.58	8.06
				(397.00)	72.60	4.60	10.60	8.00
Vb	67	>300	Dioxane	$C_{23}H_{16}N_3OSCl$	66.11	3.83	10.06	7.66
				(417.50)	66.20	3.70	10.10	7.70
Vc	62	>300	Dioxane	$C_{24}H_{19}N_3O_2S$	69.73	4.60	10.17	7.75
				(413.00)	69.60	4.70	10.20	7.90
Vd	55	>300	Dioxane	$C_{24}H_{19}N_3O_2S$	69.73	4.60	10.17	7.75
				(413.00)	69.50	4.50	10.10	7.70
VIa	30	50	Ethanol/H_2O	$C_{19}H_{18}N_2O_3S$	64.41	5.08	7.91	9.04
				(354.00)	64.20	5.00	7.80	9.00
VIb	56	210	Ethanol/H_2O	$C_{17}H_{15}N_3O_2S$	62.77	4.62	12.92	9.85
				(325.00)	62.80	4.70	12.70	10.00
VIc	64	85	Ethanol/H_2O	$C_{24}H_{21}N_3O_2S$	69.40	5.05	10.09	7.71
				(415.00)	69.30	5.10	10.20	7.90
VId	60	95	Ethanol/H_2O	$C_{24}H_{21}N_3O_3S$	66.82	4.87	9.74	7.42
				(431.00)	66.60	4.80	9.60	7.50
VIe	70	110	Ethanol/H_2O	$C_{24}H_{21}N_3O_3S$	66.82	4.87	9.74	7.42
				(431.00)	66.70	4.70	9.90	7.30
VIf	65	138	Ethanol/H_2O	$C_{23}H_{18}N_3O_2SCl$	63.37	4.13	9.64	7.35
				(435.50)	63.40	4.10	9.60	7.50
VIIa	70	125	Ethanol	$C_{22}H_{15}N_3O_2$	74.79	4.25	11.89	
				(353.00)	74.80	4.30	11.90	
VIIb	75	148	Dioxane	$C_{22}H_{14}N_3O_2Cl$	68.13	3.61	10.84	
				(387.50)	68.20	3.60	10.80	
VIIc	67	120	Ethanol	$C_{22}H_{14}N_2O_2I$	55.13	2.92	8.77	
				(478.90)	55.20	2.90	8.80	

Compd. No.	Yield (%)	M.P. (°C)	Cryst. solvent	Mol. Formula (Mol. wt)	Elemental analyses Required/Found, %			
					C	H	N	S
VIIIa	40	230	Ethanol	$C_{22}H_{19}N_3O$	77.42	5.57	12.32	
				(341.00)	77.44	5.60	12.41	
VIIIb	45	215	Ethanol	$C_{21}H_{16}N_3OCl$	69.71	4.43	11.62	
				(361.50)	69.70	4.40	11.60	
IXa	65	280	Ethanol	$C_{23}H_{16}N_4OS$	69.69	4.04	14.14	8.08
				(396.00)	69.70	4.10	14.10	8.00
IXb	55	2590	Ethanol	$C_{24}H_{18}N_4OS$	70.24	4.39	13.66	7.81
				(410.00)	70.30	4.40	13.70	7.90
X	35	122	Ethanol	$C_{18}H_{16}N_2O_2S$	66.67	4.94	8.64	9.88
				(324.00)	66.50	4.80	8.70	9.90
XIa	80	155	Ethanol	$C_{22}H_{18}N_4OS$	68.39	4.66	14.51	8.29
				(386.00)	68.40	4.70	14.30	8.10
XIh	92	158	Ethanol	$C_{22}H_{18}N_4O_2S$	65.67	4.48	13.93	7.96
				(402.00)	65.50	4.60	13.80	8.10
XIc	85	160	Ethanol	$C_{21}H_{15}N_4OSCl$	61.99	3.69	13.78	7.87
				(406.50)	62.00	3.70	13.80	8.00
XII	25	>300	Ethanol	$C_{30}H_{22}N_4O_2S_2$	67.42	4.12	10.49	11.99
				(534)	67.10	4.00	10.50	12.00
XIII	45	>300	Ethanol	$C_{22}H_{28}N_4O_6SCOCl_2$	43.56	4.62	9.24	5.28
				(606)	43.70	4.50	9.10	5.30
XIV	50	>300	Ethanol	$C_{22}H_{20}N_4O_2SCuCl_2$	49.02	3.71	10.40	4.94
				(538.55)	49.30	3.60	10.30	4.50

^{1}H nmr spectrum of (**IIIa**; DMSO-d_6) exhibited signals at: δ = 3.9 (2H,s, NH_2, exchangeable by D_2O), 4.63 (1H,s, CH), 6.8–7.5 ppm (14 H, m, Ar-H). Mass spectrum of (**IIIa**; $C_{25}H_{17}ClN_4OS$) assigned a molecular ion peak m/z at 456.5 (5.0%), with a base peak m/z 77 (100%). Other significant peaks were as follows: 390 (34%, M-H_2N-C≡C-CN); 269 (15%, thiohydantoin fragment); 188 [35%, p-ClC_6H_4CH=$C(CN)_2$]; 153 [47%, -C_6H_4-CH=$C(CN)_2$]; 76 (17% -C_6H_4-).

Formation of thieno[2,3-d]imidazole (IV)

A mixture of thiohydantoin (**II**; 0.01 mol.), chloroacetic acid (0.01 mol) and sodium ethoxide (0.01 mol) in absolute ethanol (30 mL) was refluxed 7h. The obtained solid was recrystallized from ethanol to give **IV** as rose crystals (Table-IV).

Mass spectrum of (**IV**; $C_{17}H_{12}N_2O_2S$) exhibited at m/z 308 (1%, M^+); base peak at 104 (100%, C_6H_5NC+1); 294 (49%, M-CH_2); 267 (68%, M-CH_2CO+1); 119 (9.3%, PhNCO); 103 (99%, PhNC) and 77 (64%).

Synthesis of (Va-d)

A mixture of thiohydantoin (**II**, 0.01 mol.), halogenated compounds (chloroacetanilides; 0.01 mol.) and sodium ethoxide (0.01 mol) in absolute ethanol (30 mL) was refluxed 6h. The obtained solid was recrystallized from appreciate solvent to give **Va-d** (Table IV).

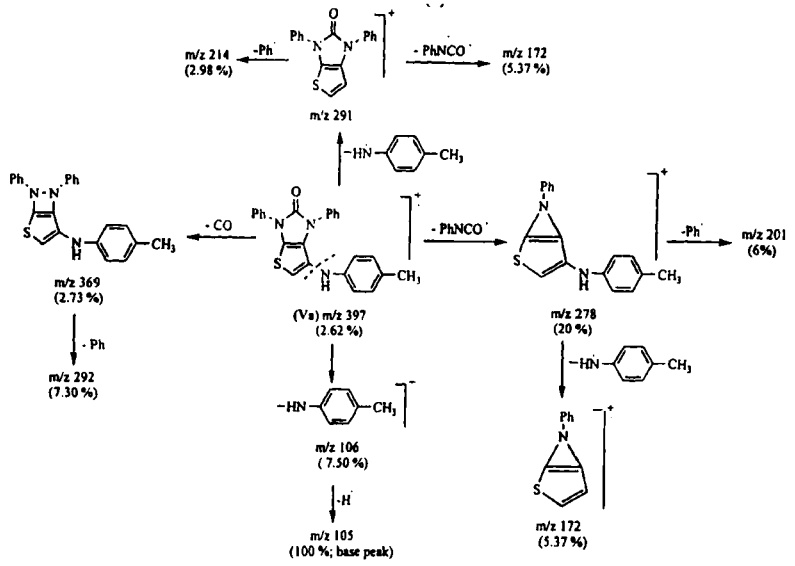
Mass spectrum of (**Va**; $C_{24}H_{19}N_3OS$) assigned a molecular ion peak at m/z 397 (2.6%, M^+); base peak 77 (100%) and other significant peaks: 368 (3.4%, M-CO); 267 (35.1%, Thiohydantoin fragment) and 104 (90.3%, C_6H_5NC+1), Scheme (4).

Formation of S-alkylated thiohydantoin (VIa-f)

A mixture of thiohydantoin (**II**, 0.01 mol.), halogenated compound (chloroacetamide, ethyl chloroacetate and chloroacetanilides; 0.01 mol.) and fused sodium acetate (0.5 gm) in absolute ethanol (30 mL) was refluxed 3h. The obtained solid was recrystallized from appreciate solvent to give **VIa-f** (Table-IV).

^1H NMR spectrum of (**VIa**; $CDCl_3$) exhibited the following signals appeared at: δ 1.2 (3H,t,CH_3), 2.9 (2H,s,S-CH_2), 4.1 (2H,q,OCH_2), 7.2–7.6 ppm (11 H, m, Ar-H+ thiohydantoin proton). Mass spectrum of compound (**VIc**; $C_{24}H_{21}N_3O_2S$) exhibited a molecular ion peak at m/z 415 (2.3%, M^+) with a base peak at 105 (100%, p-$CH_3C_6H_4N$); other peaks at 268 (64%, thiohydantoin) and 149 (40.8%, p-$CH_3C_6H_4NHCOCH_3$).

To a sample of compound (**VI**; 0.01 mol) in absolute ethanol (30 mL), sodium ethoxide (0.01 mol) was added. The mixture was refluxed for 2h. The obtained solid was recrystallized from appreciate solvent to give **V** (m.p., m.m.p. and TLC).



Fragmentation pattern of compound (**Va**)

SCHEME 4

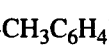
Synthesis of imidazo[2,3-d]quinolines (VIIa-c)

A mixture of thiohydantoin (**II**, 0.01 mol.), anthranilic acids (0.01 mol) and sodium methoxide (0.01 mol) in methanol (20 mL) was refluxed for 12h. The reaction mixture was then cooled, poured into crushed ice, neutralized with dil. HCl to give **VIIa-c** (Table IV).

Mass spectrum of (**VIIa**; $C_{22}H_{15}N_3O_2$) showed the following peaks a molecular ion peak at m/z 353 (1%), base peak at 341(100%), 354 (44%), 342 (18.6%), 339 (46%), 327 (13.0%), 296 (48%), 237 (86%), 220 (52%), 211 (15.0%), 206 (22%), 155 (22%), 117 (38%), 79 (22%), 62 (1%).

Formation of hydantoin (VIIIa,b)

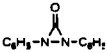
A mixture of thiohydantoin (**II**; 0.01 mol) and aromatic amines (0.01 mol) in ethanol (30 mL) was heated under reflux 7h. Concentration of the reaction mixture furnished **VIIIa,b** (Table IV).

Mass spectrum of (**VIIIa**; $C_{22}H_{19}N_3O$) showed a molecular ion peak at m/z 341 (76%, M^+) with a base peak at 104 (100%, p-$CH_3C_6H_4N$), other significant peaks were at 342 (59.6%, M+1); 340 (42.0%, M-1); 251 (73.8%, M-$CH_3C_6H_4$); 235 (61.3%, ), 91(71.5%, $C_6H_4.CH_3$) and 77 (90%, C_6H_5).

^{1}H NMR spectrum of (**VIIIa**; DMSO-d_6) exhibited the following signals: δ= 2.5 (3H,s,CH_3), 5.8 (2H,s,CH_2), 7.1–7.6 (14 H,m,Ar-H).

Thieno[2,3-d]imidazoles (IXa,b)

A mixture of thiohydantoin (**II**; 0.01 mol), cyanothioformamides (0.01 mol) and TEA (0.5 mL) in ether (50 mL) was stirred 48 h. The obtained solid was recrystallized from appreciate solvent to give **IXa,b** (Table-4).

Mass spectrum of (**IXa**; $C_{23}H_{16}N_4OS$) assigned a molecular ion peak at m/z 396 (5.3%, M^+), a base peak 77 (100%); others at 370 (18.2%, M-HCN); 336 (20.2%, M-CO and S); 293 (70.2%, M-C_6H_5NC); 211(7.9%, ) and 118 (69.3%, C_6H_5NCO-1).

Formation of 5-ethoxymethylidine-2-oxo-1,3-diphenylimidazolidine-4-thione (X)

A mixture of thiohydantoin (**II**; 0.01 mol), triethyl orthoformate (0.02 mol) in acetic anhydride (10 mL) was refluxed 1 hr. and the obtained solid was recrystallized from ethanol/ H_2O to give **X** (Table-4). ^{1}HNMR spectrum of (**X**; DMSO-d_6) exhibited the following signals: δ 1.1 (3H, t, CH_3), 4.0 (2H, q, OCH_2), 7.0–7.8 ppm (11 H, m, Ar-H + CH-methylidine).

Mass spectrum of (**X**; $C_{17}H_{12}N_2O_2S$) exhibited a molecular ion peak at m/z 324 (11.4%) a base pake at 104 (100 %), 268 (87.8%), 190 (2.9%), 149 (25.34%) and 77 (66.01 %).

Formation of 5-arylazo-4-thiohydantoin (XIa-c)

A mixture of aromatic amine (0.01 mol) was dissolved in a mixture of HCl (4 mL) and water (5 mL) and cooled to 0°C in an ice bath. To it, a cold

aqueous solution of sodium nitrite (0.69 gm) was then added. The diazonium salt so obtained was filtered into a cold mixture of sodium acetate (2 gm) and thiohydantoin (0.01 mol) in ethanol. The resulting solid was washed with water and recrystallized from appreciate solvent to give **XIa-c** (Table IV).

^{1}H NMR of (**XIa**; DMSO-d_6) δ 2.5(3H,s,CH_3), 7.1–7.7(14 H, m, Ar-H), 8.9 (1H, hump NH). Mass spectrum of (**XIa**, $C_{22}H_{18}N_4OS$) exhibited a molecular ion peak m/z at 386 (22%) with base peak at 368 (100%), 387[$(M+1)^+$; 10.4%], 369 (30.9%), 249 (9.4%), 194 (10.7%), 118 (34.6%) and 76 (26.8%).

Mass spectrum of (**XII**; $C_{30}H_{22}N_4O_2S_2$) exhibited a molecular ion peak m/z at 534 (3.4%) with a base peak m/z at 255 (100%), 410 (6.3%), 541 (8.0%), 298 (6.4%), 212 (11.8%), 158 (78.6%), 97 (43.6%) and 77 (14.2%).

Preparation of solid complexes

The solid complexes were prepared by mixing (1.0 m mol) of metal salt ($CoCl_2$, $CuCl_2$) in 30 mL of a hot ethanol solution with 30 ml of ethanol solution of appropriate amount of ligand **XIIa** (1.0 mmol.). The reaction mixture was then refluxed on a water bath for 2h. On cooling the solid complexes separated as fine precipitates which were then filtered, dried and kept in a descator over dry calcium chloride (yield 68–74%).

Photolysis of 1,3-Diphenyl-4-thiohydantoin

1,3-Diphenyl-4-thiohydantoin (**II**; 2g) was dissolved in dry acetone (200 mL) in a quartz tube was degassed by nitrogen bubbling (20 minutes), and then irradiated at room temperature for 10 hrs at λ_{max} 320 nm. with a Hanovia high pressure quartz mercury vapor lamp (700w) which had been lowered into a water cooled quartz immersion well.

For product identification, the irradiation mixtures were concentrated on a rotary evaporator below 25°C. The irradiation was conducted in degassed and sealed pyrex tubes of 5.0 mL capacity, and the yields were determined by GC analysis. Individual components were isolated by column chromatograph are compared with authentic specimens whenever possible.

T.L.C analysis using ethyl acetate / n-hexane (1:3) as eluent indicates the presence of:

Phenyl isocyanate	R_f= 0.60	Oxindole	R_f=0.36
Phenyl isothiocyanate	R_f= 0.80	2-Thioxoindole	R_f=0.70

Pyrolysis of 1,3-diphenyl-4-thiohydantoin (II)

1,3-Diphenyl-4-thiohydantoin (5 gm) was refluxed in boiling tetralin for 8 hrs. The contents of the flask were distilled under reduced pressure to remove tetralin. The pyrolysate was conducted in degassed and sealed pyrex tubes of 5.0 ml capacity, and the yields were determined by GC analysis.

Distillation under reduced pressure of the pyrolysate removed phenyl isocyanate, b.p.n ^{20}D 1.5350, m/z 119 and phenyl isothiocyanate, b.p 100°C/13 mm Hg, n ^{20}D 1.6497, its ir absorption spectrum is coincident with that of an authentic sample, m/z 135. Individual components were isolated by column chromatography and compared with authentic specimens whenever possible.

TLC analysis using ethyl acetate / n-hexane (1:3) as eluent indicates the presence of:

Phenyl isocyanate	R_f= 0.60	Oxindole	R_f=0.36
Phenyl isothiocyanate	R_f= 0.80	2-Thioxoindole	R_f=0.70

Phenyl isocyanate (4)

Identified through carbanilide formation on boiling with water, m/z 119.

Phenyl isothiocyanate (6)

b.p. 100°C/13 mmHg, n. ^{20}D 1.6497, coincident with that of authentic sample, m/z 135.

Oxindole (8)

m.p 127°C, IR spectrum identical with that of an authentic sample, m/z 133.

2-Thioxoindole (5)

m.p. 235°C, IR spectrum identical with that of an authentic sample, m/z 149.

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