Desulfurization of thioureas, benzimidazoline-2-thiones and 1,3-dihydro-1,3-diaryl-2-thioxopyrimidine-4,6(2*H*,5*H*)-diones with nickel boride at ambient temperature[1]

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Nickel boride is reported to bring about desulfurization and reductive cleavage of *N*,*N*′-diarylthioureas to give corresponding anilines and *N*-methylanilines while *N*,*N*′-dialkylthioureas have been observed to undergo desulfurization to give formamidines; benzimidazoline-2-thiones are reported to undergo desulfurization to benzimidazoles and 1,3-dihydro-1,3-diaryl-2-thioxopyrimidine-4,6(2*H*,5*H*)-diones have been observed to yield corresponding hexahydropyrimidine-4,6-diones in high yields in dry methanol at ambient temperature.

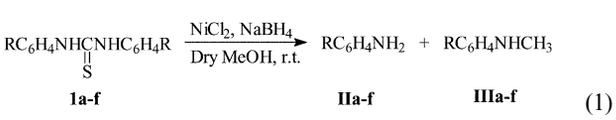
Introduction

Reductive desulfurization is an important step in organic synthesis for the removal of sulfur so as to manipulate the structure of the substrate. A variety of reagents have been used for the desulfurization of different classes of organic compounds. Desulfurization of thioureas with reagents such as $MeSO_2Cl$–Et_3N/DMAP,[2] NBS,[3] thionyl chloride,[4] di(2-pyridyl) sulfite[5] and di-2-pyridylthionocarbonate–DMAP[6] is reported to give mono- and diaryl carbodimides. Raney nickel has also been reported as a dethiating agent for thioureas, but the results are not consistent, *e.g.*, unsubstituted thioureas gave formamidine hydrochloride in the presence of ammonium chloride[7] or a mixture of methane, ammonia and methylamine;[8] *N*-(*o*-tolyl)-thiourea gave *o*-toluidine;[9] *N*,*N*′-di- and *N*,*N*,*N*′-trisubstituted thioureas have been reported to yield corresponding formamidines, while *N*-monosubstituted thioureas gave *N*,*N*′-disubstituted formamidines.[10]

The synthesis of hexahydropyrimidine-4,6-diones (some of which are of pharmaceutical importance[11]) by reductive desulfurization of 1,3-dihydro-1,3-diaryl-2-thioxopyrimidine-4,6(2*H*,5*H*)-diones (2-thiobarbiturates) has not received wide attention. Though sodium amalgam,[12] Zn-HCOOH[12] and Raney nickel[12] have been reported as dethiating agents for 2-thiobarbiturates, the yields range from low to moderate. Other factors associated with Raney nickel *e.g.*, storage, high reaction temperatures, dependence on solvent and type of Raney nickel (W-1 to W-8) also restrict its applications.[12] The alternative approach for the synthesis of hexahydropyrimidine-4,6-diones by the condensation of malonic acid derivatives with amidines, esters, acid chlorides *etc*. also suffers from certain disadvantages.[13] Therefore in our opinion a better synthesis of hexahydropyrimidine-4,6-diones is required. In recent years nickel boride[14] has been reported as a convenient and an efficient reagent for the desulfurization of mercaptans, sulfides, sulfoxides, sulfones and thioketals.[15] It has also been reported as a chemoselective reagent for deoxygenation of sulfoxides and selenoxides.[16] In view of its versatility and ease of handling, we decided to explore its application for the desulfurization of thioureas, benzimidazolinethiones and 2-thiobarbiturates.

Results and discussion

In this paper, we report reductive desulfurization of diarylthioureas (**Ia**–**h**), monoarylthioureas (**IVa**–**b**), dialkylthioureas (**Va**–**c**), benzimidazolinethiones (**VIIa**–**c**), and 2-thiobarbiturates (**IXa**–**m**) with nickel boride in dry methanol at ambient temperature. The nickel boride was prepared *in situ* from anhydrous nickel chloride and sodium borohydride. The diarylthioureas (**Ia**–**h**) underwent complete reductive desulfurization with concomitant cleavage of carbon–nitrogen bond with nickel boride using a 1:3:9 molar ratio of substrate: $NiCl_2$:$NaBH_4$except **Ib**. The reactions were complete in ~30–60 min as monitored by TLC, and gave the corresponding anilines (**II**) and *N*-methylanilines (**III**) in nearly equal ratios (eqn. 1).



(1)

a: R = H; b: R = p-CH_3; c: R = o-CH_3; d: R = p-OCH_3; e: R = o-OCH_3; f: R = p-Cl; g: R = p-Br; h: R = p-I

The reactions carried out in ethanol, DMF and THF were sluggish and showed the formation of a complex mixture of products, unlike the reactions in dry methanol. Therefore dry methanol was the solvent of choice in these reactions. Reactions of **Ia** and **Ib** when carried out with hydrated nickel chloride and ordinary methanol were very slow. Diarylthioureas (**Ia** and **Ib**) were recovered unchanged when treated with nickel chloride or sodium borohydride independently under identical conditions, thus proving the involvement of *in situ* generated nickel boride in the reactions. The reaction of *N*,*N*′-di(*p*-chlorophenyl)thiourea (**If**) with nickel boride yielded *p*-chloroaniline and *N*-methyl-*p*-chloroaniline (run 10), unlike the reactions of *N*,*N*′-di(*p*-bromophenyl) and *N*,*N*′-di(*p*-iodophenyl)thiourea which yielded a mixture of four components (runs 11,12). The mixture consisted of halogenated and dehalogenated anilines— the latter being formed by competitive dehalogenation. However, complete dehalogenation could not be achieved in either case despite using very high molar ratios of substrate to nickel chloride to sodium borohydride (1:15:45). The reactions carried out at 0 °C also showed the presence of dehalogenated products.

Monoarylthioureas (**IVa**,**b**) also underwent reductive desulfurization with concomitant carbon–nitrogen bond cleavage (eqn. 2) under the above reaction conditions. The corresponding anilines (**II**) were obtained in higher yields as compared to

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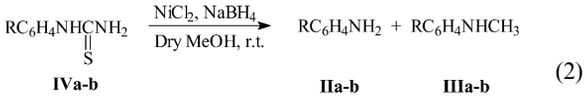
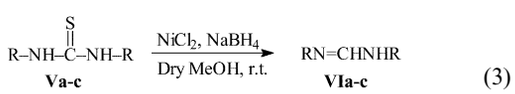
N-methylanilines (**III**) (runs 13,14). This suggests that reductive cleavage of the carbon–nitrogen bond adjacent to the aryl group is preferred over the C–NH_2 bond. This encouraged us to investigate the fate of dialkylthioureas (**Va–c**) with nickel boride under similar reaction conditions. The dialkylthiourea (**Va**) did not react as fast as diarylthioureas (**I**) and showed the formation of a mixture of products. After modifying various reaction conditions, it was observed that *N*,*N*′-di(*n*-butyl)-thiourea (**Va**) underwent complete reaction with nickel boride using a 1:5:5 molar ratio of substrate:$NiCl_2$:$NaBH_4$ in dry methanol at ambient temperature. The desulfurized product obtained was identified to be *N*,*N*′-di(*n*-butyl)formamidine (**VIa**),[17] unlike the reductive cleavage products in the reactions of di- and monoarylthioureas. Subsequently, reactions of *N*,*N*′-dicyclohexylthiourea (**Vb**) and *N*,*N*′-di(*n*-propyl)thiourea (**Vc**) with nickel boride were also found to be complete and gave the corresponding formamidines (eqn. 3).



IVa-b **IIa-b** **IIIa-b** (2)

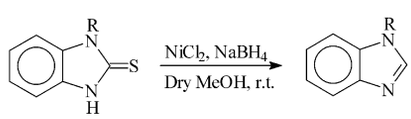
a: R = H; b: R = p-Me



Va-c **VIa-c** (3)

a: R = n–C_4H_9; b: R = c–C_6H_{11}; c: R = n–C_3H_7

The formation of formamidines as the desulfurized product in the reactions of dialkylthioureas prompted us to further investigate the reactions of cyclic thioureas. Thus reaction of benzimidazoline-2-thione (**VIIa**) was carried out with nickel boride using a 1:3:9 molar ratio (substrate:$NiCl_2$:$NaBH_4$) in dry methanol at ambient temperature. The starting material disappeared completely after 5 min (run 18) and the isolated product was identified to be benzimidazole (**VIIIa**). Subsequently, reactions of *N*-methylbenzimidazoline-2-thione (**VIIb**) and *N*-phenylbenzimidazoline-2-thione (**VIIc**) were carried out with nickel boride under identical conditions which yielded *N*-methyl- and *N*-phenylbenzimidazole (**VIIIb** and **VIIIc**), respectively (eqn. 4). All these results are tabulated in Table 1. In view of the successful reductive desulfurization of diarylthioureas (**I**), monoarylthioureas (**IV**), dialkylthioureas (**V**) and benzimidazoline-2-thiones (**VII**), we decided to investigate the desulfurization of 2-thiobarbiturates with nickel boride and optimize the conditions, as this would lead to a new method for the preparation of hexahydropyrimidine-4,6-diones.

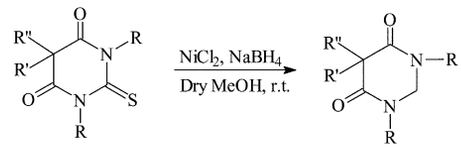


VIIa-c **VIIIa-c** (4)

a: R = H; b: R = Me; c: R = Ph

We also report herein a simple and convenient procedure for the reductive desulfurization of 2-thiobarbiturates (**IXa–m**) with nickel boride at ambient temperature to the corresponding hexahydropyrimidine-4,6-diones (**Xa–m**) in high yields (eqn. 5). Methanol was also the solvent of choice for quantitative reductive desulfurization of 2-thiobarbiturates. The reactions of **IXa** and **IXb** were not complete with sodium borohydride alone even after 48 h using a molar ratio of 1:10 (substrate:$NaBH_4$), unlike the quantitative desulfurization of **IXa** with nickel boride in ~1 h (run 23). These results are listed in Table 2.

The reagent shows high selectivity towards desulfurization since it does not affect the carbonyl groups. The rate of



IXa-m **Xa-m** (5)

a : R = Ph, R' = R"=H; b : R = p-MeC_6H_4, R' = R"=H;
c : R = o-MeC_6H_4, R' = R"=H; d : R = p-BrC_6H_4, R' = R"=H;
e : R = p-ClC_6H_4, R' = R"=H; f : R = p-$OMeC_6H_4$, R' = R"=H;
g : R = m-$OMeC_6H_4$, R' = R"=H; h : R = Ph, R' = Ph, R" = H;
i : R = R" = R' = H; j : R = R" = H, R' = Ph;
k : R = R" = H, R' = $C_6H_5CH_2$; l : R = H, R' = Ph, R" = Et
m: R = H, R' = Et, R" = $CH_3CH(CH_3)CH_2CH_2$ (isoamyl)

desulfurization is dependent on the molar ratio of substrate to nickel chloride to sodium borohydride (Table 2). The reaction of **IXd** with nickel boride gave a mixture of brominated (**Xd**) and debrominated (**Xa**) hexahydropyrimidine-4,6-diones (run 28). Completely debrominated product **Xa** was obtained using higher molar ratios of substrate:$NiCl_2$:$NaBH_4$ (run 29), whereas no dechlorinated product was isolated in the reactions of **IXe** even on using a higher molar ratio of substrate to nickel boride (run 31). These results are in agreement with previous observation on competing dehalogenation in the case of diarylthioureas (runs 10–12). This method has been utilized to prepare 5-ethyl-5-phenylhexahydropyrimidine-4,6-dione (**Xl**), a known antiepileptic agent (marketed under the trade name of 'Mysoline'), in 81% yield compared to its reported synthesis using Raney nickel in 30–45%.[12] Similarly, 1,3-diphenylhexahydropyrimidine-4,6-dione (**Xa**) could be prepared in 85% yield, compared to the reported yield of 30% using Raney nickel.[18]

Reactions of 5-monosubstituted-2-thiobarbiturates (**IXj** and **IXk**) also yielded the corresponding hexahydropyrimidine-4,6-diones (**Xj** and **Xk**) with nickel boride in high yields. However, reactions of 5-monosubstituted-2-thiobarbiturates with Raney nickel have been reported to afford corresponding 4,6-dihydroxypyrimidines.[19] Thus it can be inferred that the substitution pattern in the pyrimidine ring at C-5 **IXa–m** does not play a decisive role in the final outcome of the desulfurized product with nickel boride unlike Raney nickel.[19] The desulfurization of 5-phenyl-1,3-diphenyl-2-thiobarbituric acid (**IXh**) required a very high molar ratio of the reagent probably due to the steric crowding of the three phenyl rings (run 35). We have further observed that nickel boride loses its activity with time since no desulfurization was observed in the reactions of **IXa** and **IXb** when treated with preformed nickel boride after 72 h.

Therefore we conclude that nickel boride is an efficient reagent for reductive desulfurization of diaryl (**I**) and monoarylthioureas (**IV**) to give anilines and *N*-methylanilines; dialkylthioureas (**V**) to give formamidines and 2(1*H*)-benzimidazolinethiones (**VII**) to give benzimidazoles. It also provides a new procedure for the efficient conversion of 2-thiobarbiturates (**IX**) to corresponding hexahydropyrimidine-4,6-diones at ambient temperature.

Experimental

All the melting points were recorded on a labequip apparatus and are uncorrected. Elemental analysis was carried out on a Perkin–Elmer 2400 Series II CHNS/O analyzer. IR spectra were recorded on a Perkin–Elmer FT-IR Spectrum-2000. NMR spectra were recorded on FT-NMR model R-600 Hitachi (60 MHz) with TMS as the internal standard. Mass spectra were recorded on a JEOL JMS D-300 Spectrometer using the electron impact method (70 eV). The products were identified by co-TLC, mp, mixed mp (wherever available), IR, NMR and mass spectra.

Table 1 Reactions of thioureas and benzimidazoline-2-thiones with nickel boride in dry MeOH[a] at ambient temperature

Run	Substrate (S)	Molar ratio S:$NiCl_2$:$NaBH_4$	Time[b]/min	Products	% Isolated yield
1.	**Ia**	1:3:9	30	**IIa + IIIa**	44 + 48
2.	**Ia**	1:3:0	120	—	—[c]
3.	**Ia**	1:0:9	120	—	—[c]
4.	**Ib**	1:5:15	45	**IIb + IIIb**	44 + 40
5.	**Ib**	1:3:0	120	—	—[c]
6.	**Ib**	1:0:9	120	—	—[c]
7.	**Ic**	1:3:9	60	**IIc + IIIc**	44 + 48
8.	**Id**	1:3:9	60	**IId + IIId**	47 + 46
9.	**Ie**	1:3:9	30	**IIe + IIIe**	49 + 41
10.	**If**	1:3:9	60	**IIf + IIIf**	49 + 48
11.	**Ig**	1:3:9	30	—[d]	—
12.	**Ih**	1:3:9	30	—[d]	—
13.	**IVa**	1:3:9	30	**IIa + IIIa**	57 + 17
14.	**IVb**	1:3:9	15	**IIb + IIIb**	58 + 19
15.	**Va**	1:5:5	30	**VIa**	91
16.	**Vb**	1:5:5	30	**VIb**	95
17.	**Vc**	1:10:10	10	**VIc**	94
18.	**VIIa**	1:3:9	5	**VIIIa**	84
19.	**VIIb**	1:2:6	25	**VIIIb**	86
20.	**VIIc**	1:3:9	30	**VIIIc**	79

[a] 50 mL of the solvent was used per g of the substrate. [b] Time for disappearance of starting material. [c] The starting material was recovered unchanged. [d] The reaction mixture showed the presence of at least four components including dehalogenated products even after stirring the reaction mixture for 24 h.

Table 2 Reactions of 2-thiobarbiturates with nickel boride in dry MeOH[e] at ambient temperature.

Run	Substrate (S)	Molar ratio S:$NiCl_2$:$NaBH_4$	Time[b]/h	Product	% Isolated yield
21.	**IXa**	1:5:5	8[f]	—	—
22.	**IXa**	1:7:7	1.5	**Xa**	80
23.	**IXa**	1:10:10	1	**Xa**	85
24.	**IXb**	1:7:7	1.25	**Xb**	87
25.	**IXb**	1:10:10	0.5	**Xb**	89
26.	**IXc**	1:10:10	5	**Xc**	59
27.	**IXc**	1:5:15	7	**Xc**	79
28.	**IXd**	1:10:10	2.5	—	—[g]
29.	**IXd**	1:15:15	1	**Xa**	76[h]
30.	**IXe**	1:5:5	3	**Xe**	80
31.	**IXe**	1:10:10	0.5	**Xe**	86
32.	**IXf**	1:7:7	14	**Xf**	79
33.	**IXf**	1:10:10	2.5	**Xf**	82
34.	**IXg**	1:10:10	0.5	**Xg**	78
35.	**IXh**	1:25:25	5.25	**Xh**	85
36.	**IXi**	1:3:3	48	**Xi**	87
37.	**IXi**	1:5:5	4	**Xi**	90
38.	**IXj**	1:5:5	8[f]	—	—
39.	**IXj**	1:10:10	4	**Xj**	82
40.	**IXk**	1:10:10	3.5	**Xk**	86
41.	**IXl**	1:10:10	5.75	**Xl**	81
42.	**IXm**	1:5:5	2.5	**Xm**	82

[b] Time for disappearance of starting material. [e] 30 mL of solvent was used per g of the substrate. [f] Reaction was incomplete but showed the formation of a new product. [g] Reaction was complete and TLC showed the presence of a mixture of products. [h] The corresponding debrominated product (1,3-diphenylhexahydropyrimidine-4,6-dione) was isolated.

Starting materials

Dry MeOH was prepared by the known procedure.[20] Anhydrous $NiCl_2$ (Qualigens) was prepared by heating $NiCl_2 \cdot 6H_2O$ in a nickel crucible at 200 °C until golden yellow. $NaBH_4$ (E. Merck) was used in all the reactions. Diarylthioureas were prepared from corresponding anilines and carbon disulfide according to the reported procedure.[21] Monoarylthioureas were prepared from the corresponding anilines and ammonium thiocyanate as reported.[22] Aliphatic amines and CS_2 were used for the preparation of dialkylthiourea.[23] 2(1*H*)-Benzimidazolinethione was prepared from *o*-phenylenediamine and CS_2 by the known procedure.[24] Methylation of 2(1*H*)-benzimidazolinethione with methyl iodide gave *N*-methylbenzimidazoline-2-thione.[25] *N*-Phenylbenzimidazoline-2-thione was prepared from *o*-chloronitrobenzene, aniline and CS_2 according to the reported procedure.[26] 1,3-Diaryl-2-thiobarbiturates were synthesized by the condensation of *N*,*N*′-diarylthioureas with malonic acid in the presence of acetyl chloride.[27] C-5 substituted 2-thiobarbiturates were obtained by the condensation of thiourea with substituted diethyl malonate in the presence of sodium ethoxide.[19,28]

Reactions of diarylthioureas (I) and monoarylthioureas (IV)

In a typical experiment, 1 g (4.38 mmol) of *N*,*N*′-diphenylthiourea (**Ia**) was dissolved in 50 mL of dry methanol in a 100 mL round-bottomed flask, mounted over a magnetic stirrer. Anhydrous $NiCl_2$ 1.70 g (13.5 mmol) was added, followed by careful addition of $NaBH_4$ (1.49 g, 39.5 mmol) while stirring the solution vigorously. TLC was monitored using benzene as eluent. The reaction was found to be complete in 30 min. The

reaction mixture was filtered through a Celite pad (~1 inch) and washed with methanol (2 × 10 mL). The combined filtrate was diluted with water (~150 mL) and was extracted with ethyl acetate (3 × 10 mL). The combined extract was dried over anhydrous $MgSO_4$, filtered and concentrated on a rotary vacuum evaporator under reduced pressure. The mixture was subjected to column chromatography over silica gel (100–200 mesh) and eluted with benzene:ethyl acetate. Eluate was concentrated under reduced pressure to afford aniline (0.178 g, 44%) and *N*-methylaniline (0.22 g, 48%) which were analysed by co-TLC, superimposable IR and NMR spectra. Substituted anilines and *N*-methylanilines, obtained from substituted diaryl and monoarylthioureas, were also identified by co-TLC, IR and NMR spectra.

Reactions of dialkylthioureas (V)

In a 100 mL round-bottomed flask was placed a mixture of *N*,*N*′-di(*n*-butyl)thiourea (**Va**) (1 g, 5.32 mmol), dry methanol (50 mL) and anhydrous $NiCl_2$ (3.45 g, 26.6 mmol). 1 g (26.6 mmol) of $NaBH_4$ was added with continuous stirring. Disappearance of starting material was monitored by TLC using benzene:ethyl acetate (95:5) as eluent. The reaction was complete after 30 min. The reaction mixture was filtered through a Celite pad (~ 1 inch) and washed with methanol (2 × 10 mL). The combined filtrate was concentrated over a Buchi rotavapour and the product was triturated with dry solvent ether (3 × 10 mL) from the residue. The ether was removed from the combined extract and the isolated oil was identified to be *N*,*N*′-di(*n*-butyl)formamidine[17] (**VIa**) (0.75 g, 91%) by NMR and mass spectra. Similarly, *N*,*N*′-di(*n*-cyclohexyl)formamidine (**VIb**) was obtained as a white solid, mp 104–105 °C (lit.,[29] 106 °C) and *N*,*N*′-di(*n*-propyl)formamidine (**VIc**) was obtained as a yellow oil[17] from di(*n*-cyclohexyl)thiourea (**Vb**) and di-(*n*-propyl)thiourea (**Vc**), respectively. All the formamidines showed characteristic peak corresponding to –N–C**H**=N– at δ 7.4–7.5.

Reactions of benzimidazoline-2-thiones (VII)

A mixture of benzimidazoline-2-thione (1 g, 6.67 mmol), dry methanol (50 mL) and anhydrous $NiCl_2$ (2.6 g, 20.0 mmol) was placed in a 100 mL round-bottomed flask, fitted with a reflux condenser and a guard tube. $NaBH_4$ (2.27 g, 60.0 mmol) was carefully added with continuous stirring. The progress of the reaction was monitored using benzene:ethyl acetate (90:10) as an eluent. The starting material disappeared completely after 5 min. The reaction mixture was filtered through a Celite pad (~ 1 inch) and washed with methanol (2 × 10 mL). The combined filtrate was diluted with water (~ 150 mL) extracted with ethyl acetate (3 × 10 mL). The combined extract was dried over anhydrous $MgSO_4$, filtered and concentrated on a rotary vacuum evaporator under reduced pressure. The solid obtained was recrystallized using ethyl acetate:petroleum ether (60–80 °C) and was identified as benzimidazole (**VIIIa**) (0.66 g, 84%) by mp 171 °C (lit.,[30] 172–174 °C), co-TLC, mixed mp and NMR spectra. Similarly, *N*-methylbenzimidazole (**VIIb**), mp 58–60 °C (lit.,[30] 59–62 °C) and *N*-phenylbenzimidazole (**VIIIc**), mp 95–96 °C (lit.,[30] 97 °C) were obtained as white solids from *N*-methyl- and *N*-phenylbenzimidazoline-2-thiones (**VIIb**,**c**), respectively.

Reactions of 2-thiobarbiturates (IX)

2-Thiobarbiturates (**IX**) (1 g, *n* mmol), anhydrous $NiCl_2$-(according to Table 2) and dry methanol (30 mL) were placed in a 100 mL conical flask fitted with a condenser and a mercury trap. The flask was mounted over a magnetic stirrer. Sodium borohydride (according to Table 2) was added very cautiously while stirring the solution vigorously. The progress of the reaction was monitored by TLC using ethyl acetate-methanol as eluent. After disappearance of the starting material, the reaction mixture was filtered through a Celite pad (~ 1 inch) and washed with methanol (2 × 10 mL). The combined filtrate was diluted with water (~ 150 mL) extracted with ethyl acetate (3 × 10 mL). The combined extract was dried over anhydrous $MgSO_4$, filtered and concentrated on a rotary vacuum evaporator under reduced pressure to afford hexahydropyrimidine-4,6-diones (**X**).

In the case of **IXi**, the combined filtrate obtained after filtration of the reaction mixture over a Celite pad, was concentrated under reduced pressure. The precipitate was macerated with dry acetone (2 × 10 mL), filtered and washed with dry acetone (2 × 2 mL). The combined filtrate was concentrated on a rotary vacuum evaporator to yield hexahydropyrimidine-4,6-dione (**Xi**).

The pure samples were obtained by crystallization from ethyl acetate:petroleum ether (60–80 °C) (**Xa**–**g**) or ethanol (**Xh**–**m**), and were analysed by mp, IR, NMR and mass spectra. Thus, 1,3-diphenylhexahydropyrimidine-4,6-dione (**Xa**) mp 176–178 °C (lit.,[18] 178 °C), hexahydropyrimidine-4,6-dione (**Xi**) mp 239–240 °C (decomp.) (lit.,[31] 240–243 °C decomp.). 5-Phenyl-hexahydropyrimidine-4,6-dione (**Xj**) mp 208–210 °C (lit.,[32] 206–210 °C), 5-ethyl-5-phenylhexahydropyrimidine-4,6-dione (**Xl**) mp 280–281 °C (lit.,[12] 281–282 °C) and 5-ethyl-5-isoamyl-hexahydropyrimidine-4,6-dione (**Xm**) mp 268–270 °C (lit.,[19] 271 °C) were obtained as white solids from the corresponding 2-thiobarbiturates as described above. The spectroscopic data of newly synthesized hexahydropyrimidine-4,6-diones is listed below.

Xb: Mp 165–166 °C (white solid); anal. calc. (found) for $C_{18}H_{18}N_2O_2$: C, 73.45 (73.36); H, 6.16 (6.20); N, 9.52 (9.64)%. ν_{max} (KBr)/cm^{-1}: 1690; δ_H ($CDCl_3$, 60 MHz): 7.25 (s, 8H, Ar–H), 5.40 (s, 2H, C^2–H), 3.70 (s, 2H, C^5–H), 2.40 (s, 6H, –CH_3); *m*/*z* (EI): 294 (M^+, 55%), 224 (5), 175 (15), 119 (100), 133 (95), 91 (100).

Xc: Mp 160–161 °C (white solid); anal. calc. (found) for $C_{18}H_{18}N_2O_2$: C, 73.45 (73.54); H, 6.16 (6.24); N, 9.52 (9.61)%. ν_{max} (Nujol)/cm^{-1}: 1673; δ_H ($CDCl_3$, 60 MHz): 7.25 (s, 8H, Ar–H), 5.35 (s, 2H, C^2–H), 3.70 (s, 2H, C^5–H), 2.35 (s, 6H, –CH_3); *m*/*z* (EI): 294 (M^+, 50%), 224 (10), 175 (15), 119 (100), 133 (80), 91 (100).

Xe: Mp 149–150 °C (white solid); anal. calc. (found) for $C_{16}H_{12}Cl_2N_2O_2$: C, 57.33 (57.26); H, 3.61 (3.59); N, 8.36 (8.47)%. ν_{max} (KBr)/cm^{-1}: 1699; δ_H ($CDCl_3$, 60 MHz): 7.45 (s, 8H, Ar–H), 5.60 (s, 2H, C^2–H), 3.75 (s, 2H, C^5–H); *m*/*z* (EI): 335 (M^+, 10%), 300 (20), 266 (10), 195 (5), 153 (25), 139 (75), 105 (100).

Xf: Mp 181–182 °C (white solid); anal. calc. (found) for $C_{18}H_{18}N_2O_4$: C, 66.25 (66.49); H, 5.56 (5.60); N, 8.58 (8.40)%. ν_{max} (KBr)/cm^{-1}: 1683, 1668; δ_H ($CDCl_3$, 60 MHz): 7.0–7.4 (m, 8H, Ar–H), 5.35 (s, 2H, C^2–H), 3.85 (s, 6H, –OCH_3), 3.70 (s, 2H, C^5–H); *m*/*z* (EI): 326 (M^+, 80%), 191 (15), 149 (100), 135 (30).

Xg: Mp 192–193 °C (white solid); anal. calc. (found) for $C_{18}H_{18}N_2O_4$: C, 66.25 (66.39); H, 5.56 (5.44); N, 8.58 (8.45)%. ν_{max} (KBr)/cm^{-1}: 1680, 1660; δ_H ($CDCl_3$, 60 MHz): 6.90–7.35 (m, 8H, Ar–H), 5.35 (s, 2H, C^2–H), 3.80 (s, 6H, –OCH_3), 3.65 (s, 2H, C^5–H); *m*/*z* (EI): 326 (M^+, 82%), 191 (13), 149 (100), 135 (27).

Xh: Mp 210–213 °C (white solid); anal. calc. (found) for $C_{22}H_{18}N_2O_2$: C, 77.17 (77.09); H, 5.30 (5.42); N, 8.18 (8.40)%. ν_{max} (KBr)/cm^{-1}: 1711, 1676; δ_H ($CDCl_3$, 60 MHz): 7.20–7.60 (m, 15H, Ar–H), 5.25 (d, 2H, J = 4.5Hz, C^2–H), 5.0 (s, 1H, C^5–H); *m*/*z* (EI): 342 (M^+, 20%), 223 (15), 119 (100), 105 (17), 77 (20).

Xk: Mp 230–231 °C (white solid); anal. calc. (found) for $C_{11}H_{12}N_2O_2$: C, 64.70 (64.62); H, 5.92 (5.87); N, 13.72 (13.85)%. ν_{max} (KBr)/cm^{-1}: 3363, 3172, 1659; δ_H (DMSO-d_6, 60 MHz): 9.0 (s broad, 2H, –NH), 7.30 (s, 5H, Ar–H), 5.40 (s, 2H, C^2–H),

3.90 (t, 1H, C^5–H), 3.50 (d, 2H, $–CH_2Ph$); *m*/*z* (EI): 204 (M^+, 70%), 119 (10), 84 (75), 56 (100), 44 (10).

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