BEILSTEIN JOURNAL OF ORGANIC CHEMISTRY

Facile regiodivergent synthesis of spiro pyrrole-substituted pseudothiohydantoins and thiohydantoins via reaction of [*e*]-fused 1*H*-pyrrole-2,3-diones with thiourea

Aleksandr I. Kobelev[1], Nikita A. Tretyakov[1], Ekaterina E. Stepanova[*1], Maksim V. Dmitriev[1], Michael Rubin[*2,3] and Andrey N. Maslivets[*1]

Full Research Paper

Open Access

Address:
[1]Department of Chemistry, Perm State University, ul. Bukireva 15, Perm 614990, Russian Federation, [2]Department of Chemistry, University of Kansas, 1567 Irving Hill Road, Lawrence, Kansas 66045, United States and [3]Department of Chemistry, North Caucasus Federal University, ul. Pushkina 1a, Stavropol 355009, Russian Federation

Email:
Ekaterina E. Stepanova[*] - caterina.stepanova@psu.ru; Michael Rubin[*] - mrubin@ku.edu; Andrey N. Maslivets[*] - koh2@psu.ru

* Corresponding author

Keywords:
diversity-oriented synthesis; hydantoin; nitrogen heterocycles; rearrangement; thiourea

Beilstein J. Org. Chem. **2019,** *15,* 2864–2871.
doi:10.3762/bjoc.15.280

Received: 11 September 2019
Accepted: 11 November 2019
Published: 27 November 2019

Associate Editor: D. Spring

Abstract

A highly divergent synthesis of regioisomeric thiohydantoins and pseudothiohydantoins spiro-fused to a pharmacologically valuable pyrrole-2-one fragment involving the reaction of [*e*]-fused 1*H*-pyrrole-2,3-diones with thioureas was developed. The obtained spiro pseudothiohydantoin derivatives were found to undergo a pseudothiohydantoin–thiohydantoin rearrangement. The reactions were shown to proceed under catalyst-free conditions in good yields, and the products were isolated without applying preparative chromatography methods.

Introduction

Hydantoin (imidazolidine-2,4-dione) derivatives are omnipresent among biologically active compounds [1]. Many of them are commercially available drugs, for example, anticonvulsants phenytoin [2] and albutoin [3], the muscle relaxant dantrolene [4], or the nonsteroidal antiandrogen agent enzalutamide [5] (Figure 1).

Despite this fact, hydantoin derivatives belong to a special group of scaffolds in medicinal chemistry. Indeed, they are structurally related to rhodanine (2-thioxothiazolidin-4-one), and sometimes are classified as pan-assay interference compounds (PAINS), which are abhorrent in high-throughput screenings [6]. To clarify whether such compounds are privi-

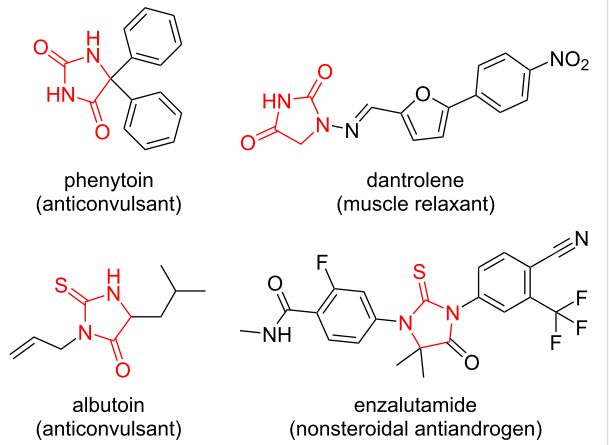
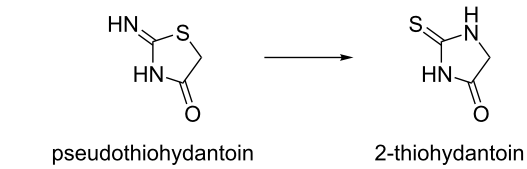


Figure 1: Hydantoin-based commercially available drugs.

leged scaffolds or promiscuous binders, Mendgen and co-workers performed a systematic comparative study on rhodanines and related structures with respect to their medicinal chemistry properties [7]. As a result, it was shown that such structures could be suitable scaffolds for medicinal chemistry under proper conditions of biological evaluation, while their medicinal chemistry properties dramatically depend on the structure of the five-membered heterocyclic moiety and substituents in the C-5 position [7].

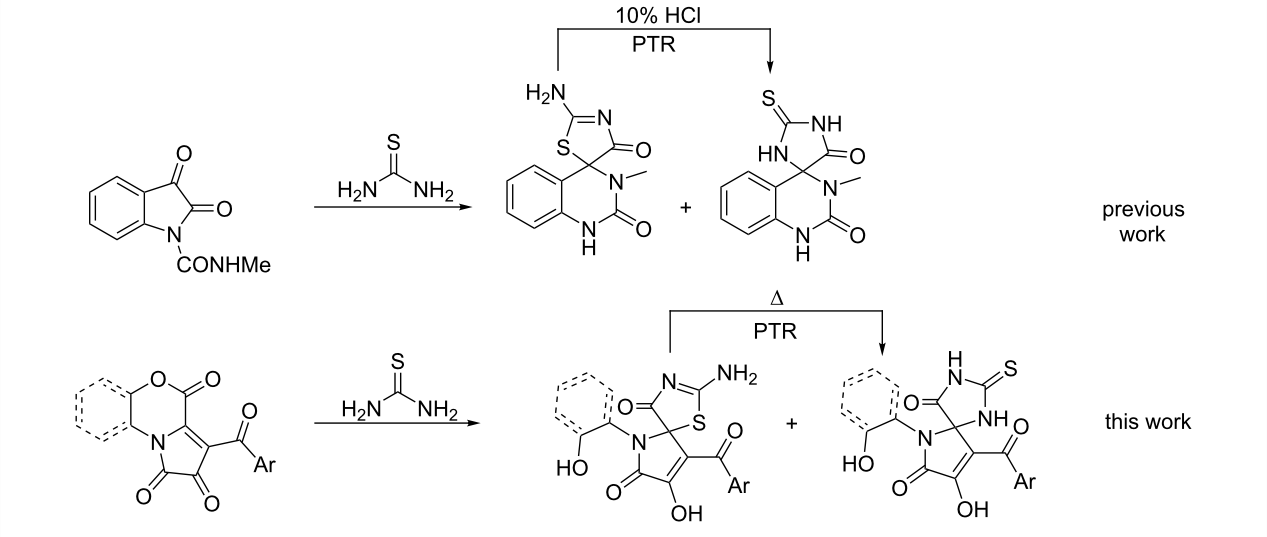
Some pseudothiohydantoins (2-iminothiazolidin-4-ones) are known to undergo a pseudothiohydantoin–thiohydantoin rearrangement (PTR, Scheme 1) [8-11], which is a special case of a quite poorly investigated iminothiolactone–thiolactam rearrangement [12-16]. This reaction offers attractive opportunities for the design of libraries of regioisomeric hydantoin-based compounds for drug discovery.



Scheme 1: Pseudothiohydantoin–thiohydantoin rearrangement.

Spiro heterocycles are relatively new and insufficiently investigated structures in medicinal chemistry [17,18]. The introduction of spiro-fused cyclic moieties in small molecules increases the degree of their structural (shape) complexity, which may lead to the reduced binding promiscuity and improved clinical success [19]. Thus, recent development of 3D modelling methods facilitated investigations on the importance of 3D properties of small-molecular drug candidates [20-22] and inspired chemists to develop diversity-oriented methods for complex 3D molecules [23,24].

Considering that to the best of our knowledge, only a sole report exists [10] that describes the synthesis of regioisomeric 5-spiro-substituted thiohydantoins and pseudothiohydantoins and their PTR (Scheme 2), we were encouraged to develop a divergent synthetic approach to access regioisomeric thiohydantoins and pseudothiohydantoins that are spiro-fused to a pharmacologically valuable pyrrole-2-one fragment and to investigate the scope and conditions of their PTR behavior (Scheme 2).



Scheme 2: Syntheses of regioisomeric 5-spiro-substituted thiohydantoins and pseudothiohydantoins: previous [10] and this work.

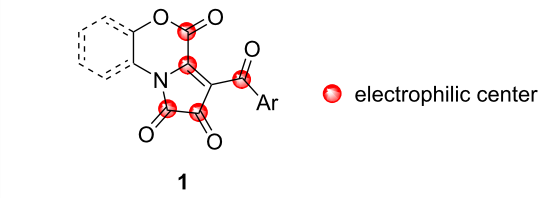
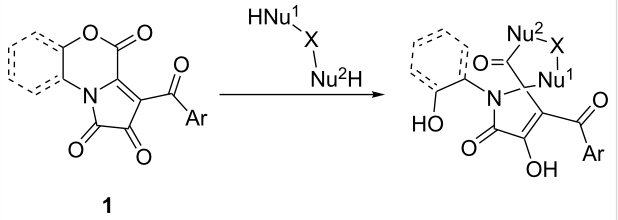


Figure 2: Electrophilic centers of FPDs **1**, starting materials of this study.



Scheme 3: Cyclocondensation of FPDs **1** with 1,3-binucleophilic reagents, resulting in pyrrole-2-one-bearing spiro[4.4] heterocycles.

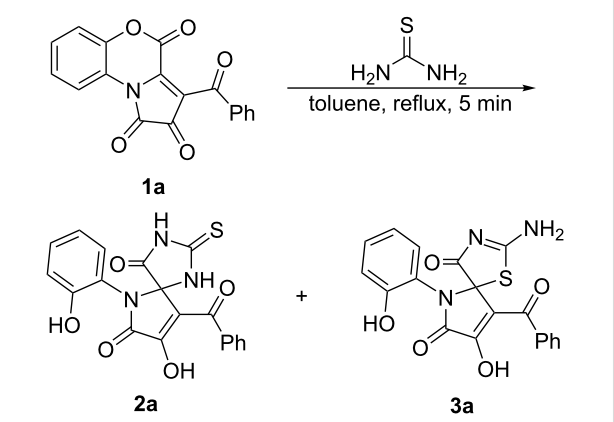
Results and Discussion

1*H*-Pyrrole-2,3-diones fused at [*e*]-side (FPDs) **1** can be viewed as a versatile polyelectrophilic synthetic platform (Figure 2), enabling facile preparation of libraries of heterocyclic molecules with an emphasis on skeletal diversity from a single set of reagents [25-27].

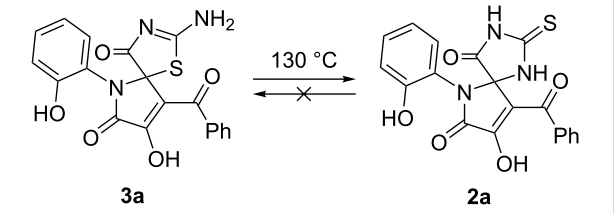
One of the most intriguing chemical properties of FPDs **1** is their ability to undergo a cyclocondensation with 1,3-binucleophilic reagents to form spiro[4.4] heterocycles bearing a pharmacophoric pyrrole-2-one moiety (Scheme 3) [28,29]. We employed this feature as a key step in the development of a straightforward and concise synthetic approach towards regioisomeric thiohydantoins and pseudothiohydantoins spiro-fused to a pyrrole-2-one fragment.

To test the preparation of the target spiro-fused pseudothiohydantoins and thiohydantoins, we examined the reaction of FPD **1a** with thiourea by heating equimolar amounts of the reagents in toluene for 5 min (until the disappearance of the dark violet color of FPD **1a**). The reaction mixture was examined by UPLC–MS. Two major products with m/z = 396 ($[M + H]^+$, ESI^+) were observed in a ratio of ≈1:1, which corresponded to adducts of thiourea with FPD **1a**. The adducts were isolated, and their structures were elucidated as the desired spiro-fused thiohydantoin **2a** and pseudothiohydantoin **3a** (Scheme 4).

It should be pointed out that earlier, we have communicated initial data on this transformation [30,31]. However, taking into account more advanced structure elucidation methods employed in the present work (e.g., NMR, single crystal X-ray



Scheme 4: Reaction of FPD **1a** with thiourea.



Scheme 5: PTR of **3a** to **2a**.

diffraction), we concluded that the structures of the products were identified incorrectly, and they are revised herein (for a detailed revision see Supporting Information File 1).

Next, to find out whether compounds **2a** and **3a** were prone to undergo PTR, they were heated in open capillaries at 130 °C for 2 h, and the resulting mixtures were examined by UPLC–MS. As a result, we found that compound **2a** did not rearrange, and compound **3a** partially converted into its regioisomer **2a** due to irreversible PTR (Scheme 5).

Possibly, when carrying out the reaction of FPD **1a** with thiourea by refluxing the reaction mixture in toluene, part of the product **3a** was converted into **2a** because of PTR. We assumed that at lower temperatures, the main product of the reaction could be pseudothiohydantoin **3a**. To prove this assumption, we examined the reaction of FPD **1a** with thiourea at room temperature in various solvents (Table 1).

Obviously, the ratio of products **2a** and **3a** was dependent not only on the temperature of the reaction, but also on the polarity of the solvent. We found that optimal conditions for dominant formation of pseudothiohydantoin **3a** were applied by stirring the reaction mixture at room temperature in ethyl or butyl acetate (Table 1, entries 2 and 6).

Table 1: Reaction of FPD **1a** with thiourea at room temperature in various solvents.[a]

Entry	Solvent	**2a**:**3a**[b]
1	acetone	30:70
2	ethyl acetate	5:95
3	1,4-dioxane	50:50
4	acetic acid	30:70
5	acetonitrile	50:50
6	butyl acetate	5:95
7	toluene	traces[c]

[a]Reaction mixtures were stirred until the disappearance of the dark violet color of FPD **1a** (about 2–4 h). [b]According to UPLC–MS data. [c]The reaction proceeded too slowly, and FPD **1a** underwent hydrolysis faster than reaction with thiourea (the reaction vessel was contaminated with water during samplings for analyses).

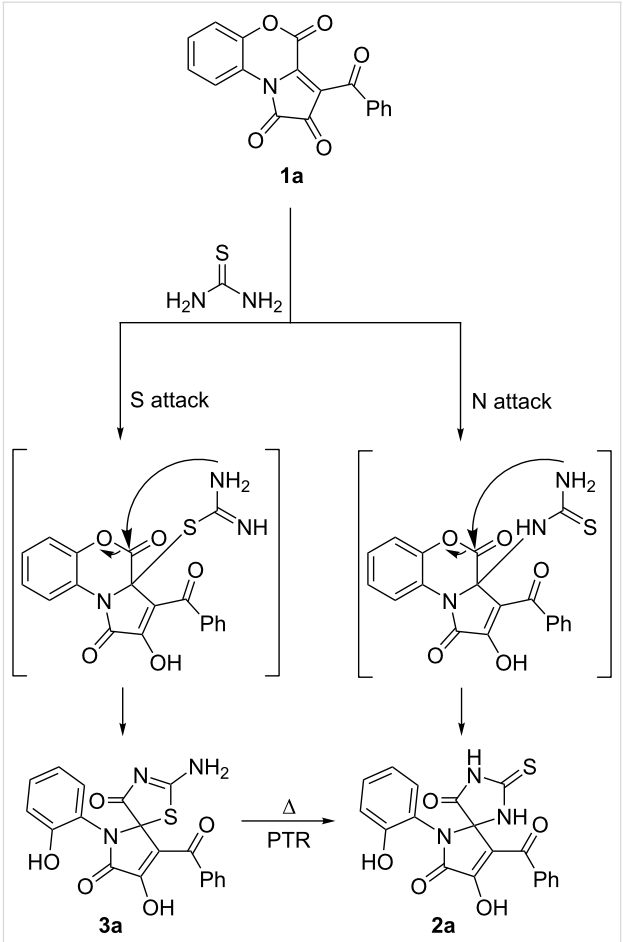
For the development of a convenient procedure for thiohydantoin **2a** without isolation of its regioisomer **3a** being required, we carried out the reaction of FPD **1a** with thiourea in various solvents under reflux (Table 2).

Table 2: Reaction of FPD **1a** with thiourea at reflux in various solvents.[a]

Entry	Solvent	**2a**:**3a**[b]
1	acetone	30:70[c]
2	ethyl acetate	22:78[c]
3	1,4-dioxane	90:10[c]
4	1,4-dioxane	99:1[d]
5	acetic acid	30:70[c]
6	acetonitrile	25:75[c]
7	butyl acetate	95:5[c]
8	toluene	50:50[c]

[a]Reaction mixtures were refluxed until the disappearance of the dark violet color of FPD **1a** (about 5–15 min). [b]According to UPLC–MS data. [c]The reagents were mixed prior the heating. [d]Thiourea was added to a boiling solution of FPD **1a**.

As a result of this optimization, we established that thiohydantoin **2a** was formed as major product upon refluxing the reaction mixture in butyl acetate or 1,4-dioxane (Table 2, entries 3, 4, and 7). Interestingly, at different reagent ratios, the yield of compound **2a** was affected as well (Table 2, entries 3 and 4). When the reagents were mixed prior to heating (Table 2, entry 3), the yield of compound **2a** was lower than when the reagents were mixed in the boiling solvent (Table 2, entry 4). Probably, compound **2a** was formed not only as a result of the corresponding PTR, but as a result of a concurrent attack of the amino group of thiourea on the C-3a atom of FPD **1a** (Scheme 6).



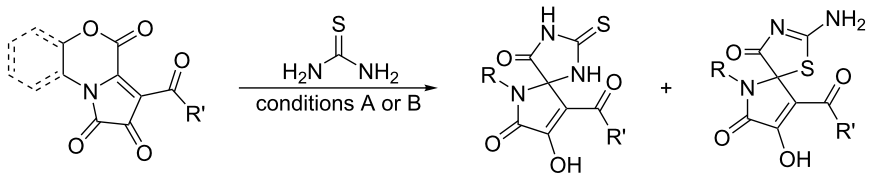
Scheme 6: Pathways for the formation of compound **2a**.

Using the optimization data, we obtained a series of spiro-fused thiohydantoins **2a**–**m** and pseudothiohydantoins **3a**–**m** by utilizing various FPDs **1a**–**n** (Table 3). The aryl group-bearing FPDs **1a**–**m** reacted facilely to yield the desired compounds **2** and **3**, but ethoxycarbonyl group-bearing FPD **1n** reacted unselectively, giving a complex mixture of hardly identifiable products due to the occurrence of multiple side reactions involving the ethoxycarbonyl group.

Next, we examined the influence of substituents in the thiourea motif on its reaction with FPDs **1**. It was found that monosubstituted thioureas (*N*-methylthiourea, *N*-phenylthiourea, *N*-(4-chlorophenyl)thiourea, *N*-(3,5-dimethylphenyl)thiourea, *N*-(4-nitrophenyl)thiourea, and *N*-1-naphtylthiourea) reacted with FPD **1a** unselectively, forming a mixture of four inseparable adducts (the reaction mixtures were analyzed by UPLC–MS) (Scheme 7). Unfortunately, we did not succeed to find any conditions for a selective formation of either of them.

Unexpectedly, the implementation of *N*-acetylthiourea in the reaction with FPDs **1**, both under conditions A and B (see Ta-

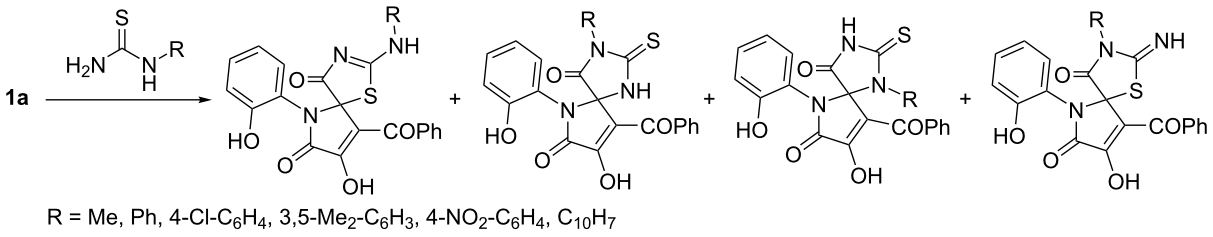
Table 3: Series of spiro-fused thiohydantoins **2a–m** and pseudothiohydantoins **3a–m** from various FPDs **1a–n**.



1a–m **2a–m** **3a–m**

Entry	R	R'	Yield of **2** (%)[a,b]	Yield of **3** (%)[a,c]
a	2-OH-C_6H_4	Ph	97 (CCDC 1952743)	79
b	5-Cl-2-OH-C_6H_3	Ph	78	87
c	2-OH-C_6H_4	4-OMe-C_6H_4	79	91
d	2-OH-C_6H_4	4-OEt-C_6H_4	90	79
e	2-OH-C_6H_4	4-Cl-C_6H_4	78	61 (CCDC 1952745)
f	2-OH-C_6H_4	4-Br-C_6H_4	87	61
g	2-OH-C_6H_4	4-Me-C_6H_4	89	89
h	5-NO_2-2-OH-C_6H_3	Ph	95	58
i	2-OH-C_6H_4	4-NO_2-C_6H_4	61	53
j	5-Br-2-OH-C_6H_3	Ph	65	59
k	2-OH-C_6H_4	4-F-C_6H_4	81	82
l	CH_2CH_2OH	4-Cl-C_6H_4	90 (CCDC 1952798)	97
m	CH_2CH_2OH	4-Me-C_6H_4	98	75
n	2-OH-C_6H_4	OEt	–	–

[a]Isolated yields. [b]Conditions A: a mixture of FPD **1a–n** (1 mmol) and thiourea (1 mmol) was refluxed in 1,4-dioxane (5 mL) for 4 h. [c]Conditions B: a mixture of FPD **1a–n** (1 mmol) and thiourea (1 mmol) was stirred in ethyl acetate (5 mL) for 12 h at room temperature.



Scheme 7: Reaction of FPD **1a** with monosubstituted thioureas.

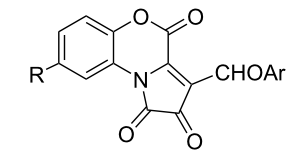
ble 3), afforded only one type of adducts, pseudothiohydantoins **4** (Table 4). Boiling compounds **4** in various solvents and heating them in open capillaries at 130 °C for 12 h did not provoke PTR, and compounds **4** remained unconverted. This phenomenon could be explained by the influence of the electron-withdrawing effect of the acetyl group, which reduced the nucleophilic properties of the acetyl-substituted nitrogen atom in *N*-acetylthiourea and decreased its reactivity, preventing the formation of regioisomeric compounds.

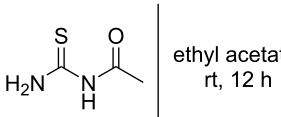
1,3-Dibutylthiourea reacted smoothly at room temperature in ethyl acetate with FPDs **1** to form mixtures of products **5** and **6** (Scheme 8). Moreover, it was observed that the percentage of compounds **5** in reaction mixtures increased over time upon storage of the solutions. As such, **6** readily underwent PTR, affording the corresponding compounds **5**, but unfortunately, we did not succeed to isolate pseudothiohydantoins **6**.

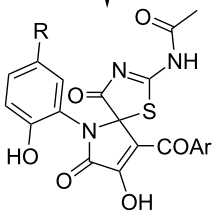
The reaction of FPDs **1** with 1,3-dibutylthiourea in 1,4-dioxane resulted in exclusive formation of thiohydantoins **5** upon heating at reflux for 2–4 h (Table 5).

The facility of thiohydantoins **5** formation could be explained by the electron-donating effect of the butyl substituents, which

Table 4: [b]Reaction of FPDs **1** with *N*-acetylthiourea.



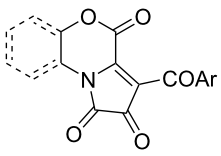


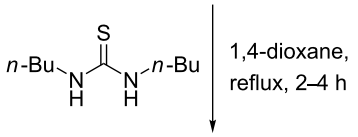


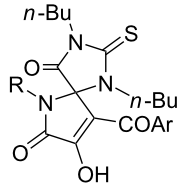
Product	Ar	R	Yield of **4** (%)[a]
4a[b]	Ph	H	80
4b	4-Cl-C_6H_4	H	75
4c	Ph	Cl	79

[a]Isolated yields. [b]CCDC 1952746.

Table 5: Reaction of FPDs **1** with 1,3-dibutylthiourea at reflux.

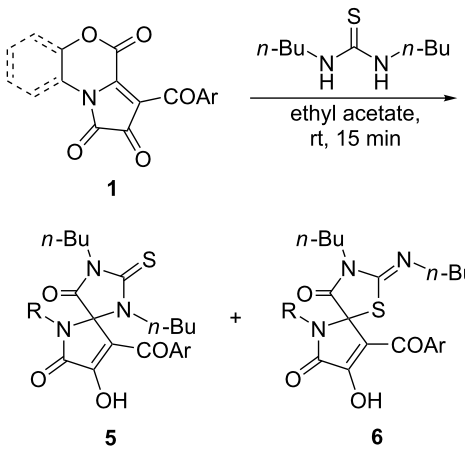






Product	Ar	R	Yield of **5** (%)[a]
5a	Ph	2-OH-C_6H_4	75
5b[b]	Ph	5-Cl-2-OH-C_6H_3	76
5c	4-Cl-C_6H_4	CH_2CH_2OH	76

[a]Isolated yields. [b]CCDC 1952744.



Scheme 8: Reaction of FPDs **1** with 1,3-dibutylthiourea at room temperature.

increased the nucleophilicity of the butyl-substituted nitrogen atoms and promoted its attack on the electrophilic center C-3a of FPDs **1**.

The reaction of FPDs **1** with 1,3-diphenylthiourea proceeded in a similar manner. Thiohydantoins **7** were predominantly formed when the reaction was conducted at reflux in 1,4-dioxane, and pseudothiohydantoins **8** were formed as main products at room temperature (Table 6).

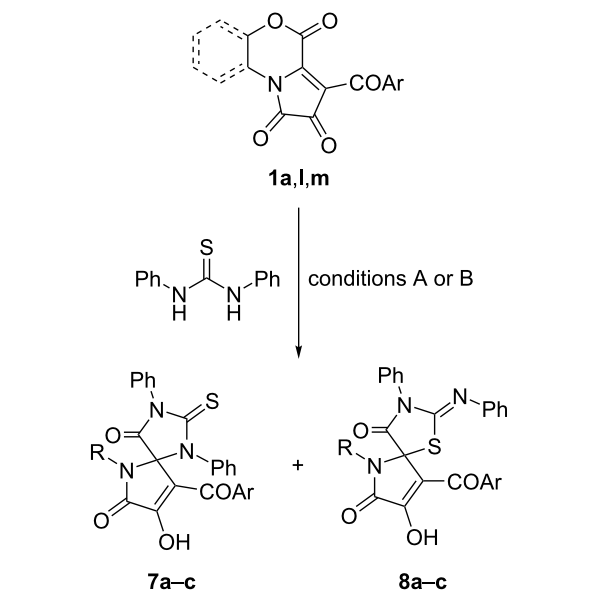
Notably, the formation of thiohydantoins **7** required longer time in comparison with unsubstituted thiourea and 1,3-dibutylthiourea. Possible reasons for this are the influence of the steric hindrance induced by the phenyl substituents and weakening of the nucleophilic properties of the phenyl-substituted nitrogen atom, which prevented a nucleophilic attack of 1,3-diphenylthiourea on the electrophilic center C-3a of FPDs **1**.

The observed PTRs could have proceed through two alternative pathways (Scheme 9), with the first stage being dissociation of the C_{spiro}–S bond [32] in pseudothiohydantoins **PThH**, affording intermediate **A**. Then, **A** could have further undergone either an intramolecular cyclization by NH attack, forming thiohydantoin **ThH** (path A), or further dissociation to FPD **1** and thiourea. The latter would subsequently attack FPD **1** with both nucleophilic NH centers, forming thiohydantoin **ThH** (path B).

Conclusion

In conclusion, we have developed a divergent approach to pharmaceutically interesting regiomeric thiohydantoins and

Table 6: Reaction of FPDs **1** with 1,3-diphenylthiourea.



Entry	Ar	R	Yield of **7** (%)[a,b]	Yield of **8** (%)[a,c]
a	Ph	2-OH-C_6H_4	71	78
b	4-Cl-C_6H_4	CH_2CH_2OH	63	82
c	4-Me-C_6H_4	CH_2CH_2OH	72	76

[a]Isolated yields. [b]Conditions A: a mixture FPD **1** (1 mmol) and 1,3-diphenyl-thiourea (1 mmol) was refluxed in 1,4-dioxane (5 mL) for 8–12 h. [c]Conditions B: a mixture FPD **1** (1 mmol) and 1,3-diphenyl-thiourea (1 mmol) was stirred in ethyl acetate (5 mL) for 12 h at room temperature.

pseudothiohydantoins spiro-fused to a pyrrole-2-one fragment via the reaction of [*e*]-fused 1*H*-pyrrole-2,3-diones with thioureas. The obtained pseudothiohydantoins were found to be prone to undergo a pseudothiohydantoin–thiohydantoin rearrangement. Therein, the substituents of the thiourea moiety were found to be crucial for tuning the conditions of this rearrangement. Notably, the reactions proceeded under catalyst-free conditions with good yields.

Supporting Information

Supporting Information File 1

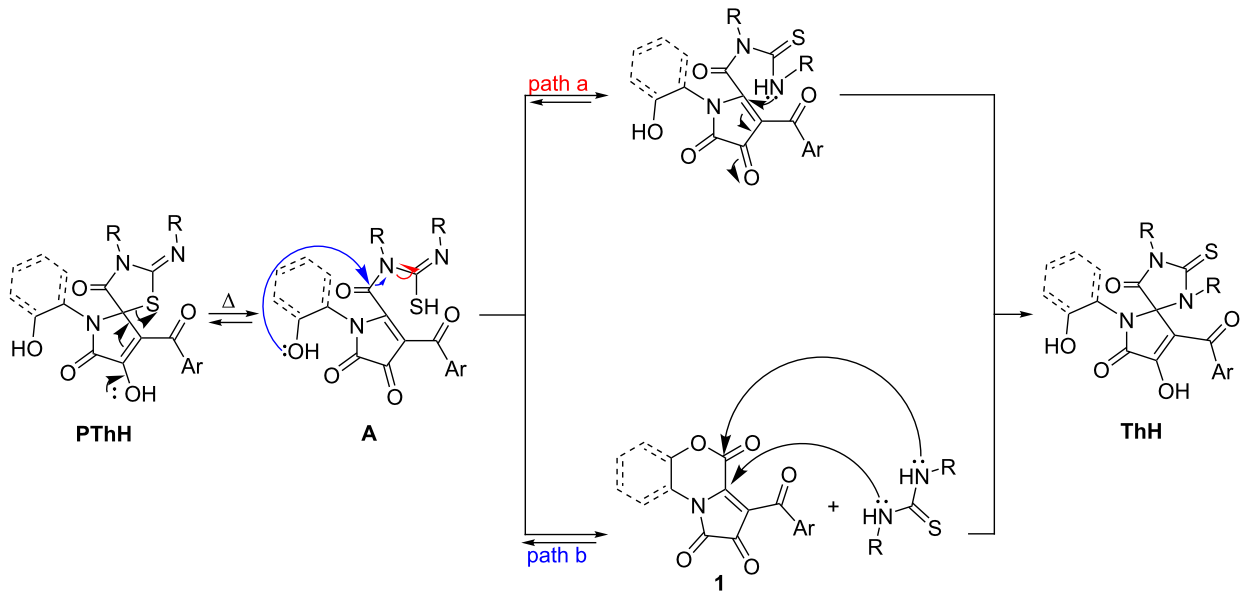
Experimental details, copies of ^{1}H and ^{13}C NMR spectra, X-ray crystallographic details, references to antimicrobial assay results, and a detailed revision of previously published structures.
[https://www.beilstein-journals.org/bjoc/content/supplementary/1860-5397-15-280-S1.pdf]

Acknowledgements

The study was performed under the financial support of the Russian Ministry of Education and Science (project no. 4.6774.2017/8.9) and the Government of Perm Krai.

ORCID® iDs

Aleksandr I. Kobelev - https://orcid.org/0000-0001-8606-7908
Nikita A. Tretyakov - https://orcid.org/0000-0002-6375-9407
Ekaterina E. Stepanova - https://orcid.org/0000-0002-5851-3082
Maksim V. Dmitriev - https://orcid.org/0000-0002-8817-0543



Scheme 9: Plausible PTR pathways.

Michael Rubin - https://orcid.org/0000-0002-1668-9311
Andrey N. Maslivets - https://orcid.org/0000-0001-7148-4450

References

1. Konnert, L.; Lamaty, F.; Martinez, J.; Colacino, E. *Chem. Rev.* **2017,** *117,* 13757–13809. doi:10.1021/acs.chemrev.7b00067
2. World Health Organization Model List of Essential Medicines, 21st List. World Health Organization: Geneva, 2019; https://www.who.int/medicines/publications/essentialmedicines/ (accessed Sept 11, 2019).
3. Krause, T.; Gerbershagen, M. U.; Fiege, M.; Weißhorn, R.; Wappler, F. *Anaesthesia* **2004,** *59,* 364–373. doi:10.1111/j.1365-2044.2004.03658.x
4. Cereghino, J. J.; Brock, J. T.; Van Meter, J. C.; Kiffin Penry, J.; Smith, L. D.; Fisher, P.; Ellenberg, J. *Clin. Pharmacol. Ther. (Hoboken, NJ, U. S.)* **1974,** *15,* 406–416. doi:10.1002/cpt1974154406
5. Bianchini, D.; Lorente, D.; Rodriguez-Vida, A.; Omlin, A.; Pezaro, C.; Ferraldeschi, R.; Zivi, A.; Attard, G.; Chowdhury, S.; de Bono, J. S. *Eur. J. Cancer* **2014,** *50,* 78–84. doi:10.1016/j.ejca.2013.08.020
6. Baell, J. B.; Holloway, G. A. *J. Med. Chem.* **2010,** *53,* 2719–2740. doi:10.1021/jm901137j
7. Mendgen, T.; Steuer, C.; Klein, C. D. *J. Med. Chem.* **2012,** *55,* 743–753. doi:10.1021/jm201243p
8. Ulrich, H.; Sayigh, A. A. R. *J. Org. Chem.* **1965,** *30,* 2781–2783. doi:10.1021/jo01019a067
9. Schaumann, E.; Grabley, S. *Justus Liebigs Ann. Chem.* **1978,** 1568–1585. doi:10.1002/jlac.197819781004
10. Yamagishi, M.; Ozaki, K.-i.; Yamada, Y.; Da-Te, T.; Okamura, K.; Suzuki, M. *Chem. Pharm. Bull.* **1991,** *39,* 1694–1698. doi:10.1248/cpb.39.1694
11. El-Aasar, N. K.; Saied, K. F. *J. Heterocycl. Chem.* **2008,** *45,* 645–652. doi:10.1002/jhet.5570450302
12. Makarenko, A. G.; Parkhomenko, P. I.; Rozhenko, A. B.; Grigor'ev, A. A.; Rybakova, M. V.; Bezuglyi, Y. V. *Chem. Heterocycl. Compd.* **1994,** *30,* 1106–1109. doi:10.1007/bf01171175
13. Fathalla, W. M.; Pazdera, P. *Molecules* **2002,** *7,* 96–103. doi:10.3390/70100096
14. Briel, D.; Aurich, R.; Egerland, U.; Unverferth, K. *Pharmazie* **2005,** *60,* 732–735.
15. Hilmy, K. M. H.; Soliman, D. H.; Shahin, E. B. A.; El-Deeb, H. S.; El-Kousy, S. M. *Eur. J. Med. Chem.* **2014,** *78,* 419–424. doi:10.1016/j.ejmech.2014.03.068
16. Belikov, M. Y.; Fedoseev, S. V.; Ievlev, M. Y.; Ershov, O. V. *Chem. Heterocycl. Compd.* **2017,** *53,* 1057–1060. doi:10.1007/s10593-017-2170-1
17. Marson, C. M. *Chem. Soc. Rev.* **2011,** *40,* 5514–5533. doi:10.1039/c1cs15119c
18. Zheng, Y.; Tice, C. M.; Singh, S. B. *Bioorg. Med. Chem. Lett.* **2014,** *24,* 3673–3682. doi:10.1016/j.bmcl.2014.06.081
19. Lovering, F. *MedChemComm* **2013,** *4,* 515–519. doi:10.1039/c2md20347b
20. Sauer, W. H. B.; Schwarz, M. K. *J. Chem. Inf. Comput. Sci.* **2003,** *43,* 987–1003. doi:10.1021/ci025599w
21. Aldeghi, M.; Malhotra, S.; Selwood, D. L.; Chan, A. W. E. *Chem. Biol. Drug Des.* **2014,** *83,* 450–461. doi:10.1111/cbdd.12260
22. Mohammad, H. B.; Khurshid, A.; Sudeep, R.; Jalaluddin, M. A.; Mohd, A.; Mohammad, H. S.; Saif, K.; Mohammad, A. K.; Ivo, P.; Inho, C. *Curr. Pharm. Des.* **2016,** *22,* 572–581. doi:10.2174/1381612822666151125000550
23. Hung, A. W.; Ramek, A.; Wang, Y.; Kaya, T.; Wilson, J. A.; Clemons, P. A.; Young, D. W. *Proc. Natl. Acad. Sci. U. S. A.* **2011,** *108,* 6799–6804. doi:10.1073/pnas.1015271108
24. Murray, C. W.; Rees, D. C. *Angew. Chem., Int. Ed.* **2016,** *55,* 488–492. doi:10.1002/anie.201506783
25. Stepanova, E. E.; Kasatkina, S. O.; Dmitriev, M. V.; Maslivets, A. N. *Synthesis* **2018,** *50,* 4897–4904. doi:10.1055/s-0037-1610647
26. Kobelev, A. I.; Stepanova, E. E.; Dmitriev, M. V.; Maslivets, A. N. *Beilstein J. Org. Chem.* **2019,** *15,* 364–370. doi:10.3762/bjoc.15.32 10.3762/bjoc.15.32.
27. Kasatkina, S.; Stepanova, E.; Dmitriev, M.; Mokrushin, I.; Maslivets, A. *Tetrahedron Lett.* **2019,** *60,* No. 151088. doi:10.1016/j.tetlet.2019.151088
28. Konovalova, V. V.; Shklyaev, Y. V.; Maslivets, A. N. *ARKIVOC (Gainesville, FL, U. S.)* **2015,** No. i, 48–69. doi:10.3998/ark.5550190.p008.889
29. Konovalova, V. V.; Maslivets, A. N. *Mini-Rev. Org. Chem.* **2019,** *16,* 173–192. doi:10.2174/1570193x15666180712115204
30. Mashevskaya, I. V.; Kol'tsova, S. V.; Voronina, E. V.; Odegova, T. F.; Maslivets, A. N. *Pharm. Chem. J.* **2001,** *35,* 18–21. doi:10.1023/a:1010494525001
31. Babenysheva, A. V.; Maslivets, V. A.; Maslivets, A. N. *Russ. J. Org. Chem.* **2007,** *43,* 1577–1578. doi:10.1134/s107042800710034x
32. Kobelev, A. I.; Stepanova, E. E.; Dmitriev, M. V.; Denislamova, E. S.; Maslivets, A. N. *Russ. J. Org. Chem.* **2018,** *54,* 766–770. doi:10.1134/s1070428018050159

License and Terms