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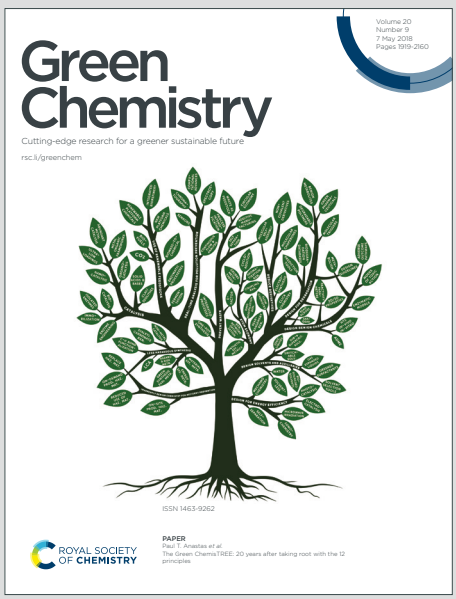

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ARTICLE

Visible Light-Mediated Metal-Free Double Bond Deuteration of Substituted Phenylalkenes

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Various bromophenylalkenes were reductively photodebrominated by 1,3-dimethyl-2-phenyl-1*H*-benzo-[d]imidazoline (**DMBI**) and 9,10-dicyanoanthracene. With deuterated **DMBI** analogs (the most effective was **DMBI-d_{11}**), satisfactory to excellent isotopic yields were reached. **DMBI-d_{11}** could also be regenerated from reaction mixtures by up to 50%. The combination of the photodebromination reaction with conventional methods for bromoalkenes synthesis enables sequential monodeuteration of double bond without necessity of a metal catalyst.

Introduction

Deuteration of organic compounds is of considerable significance in numerous areas of chemistry and chemical biology. Deuterated compounds became an essential tool for reaction mechanism studies[1,2,3] or structure elucidation.[4–6] Deuterium incorporation may be highly beneficial also for drug discovery due to the inhibition of the drug metabolism. It also enables "evergreening" of expired patents on previously discovered drugs.[7–9]

As deuterated synthetic building blocks are usually costly, their implementation to an extended reaction sequence is inefficient for preparation of the compound on a larger scale. Also, complex natural compounds eligible for isotopic enrichment do not allow the use of deuterated precursor. The post-synthetic transformation is the only feasible way of deuterium implementation in these cases.

One of the relevant groups deserving attention is the phenylvinyl fragment, which can be found in many approved drugs, like entacapone, rilpivirine or cyclobenzaprine, natural compounds including flavones, chalcones, stilbenoids or more complex compounds like semisynthetic lysergic acid derivatives, salvianolic acid A, etc. (Figure 1). Although there are various methods for its deuteration, the drawbacks include low selectivity, isotopic yield, and configuration stability along with toxicity of heavy metal catalysts or influence of too reactive species on functional groups. These facts force chemists to study alternative deuteration procedures.

Recently published methods include direct H/D exchange or replacement of various reactive groups. Deuterium can be transferred from deuterated solvents under transition-metal catalysis[10–12] or by hydrolysis of organolithium compounds.[13–16]

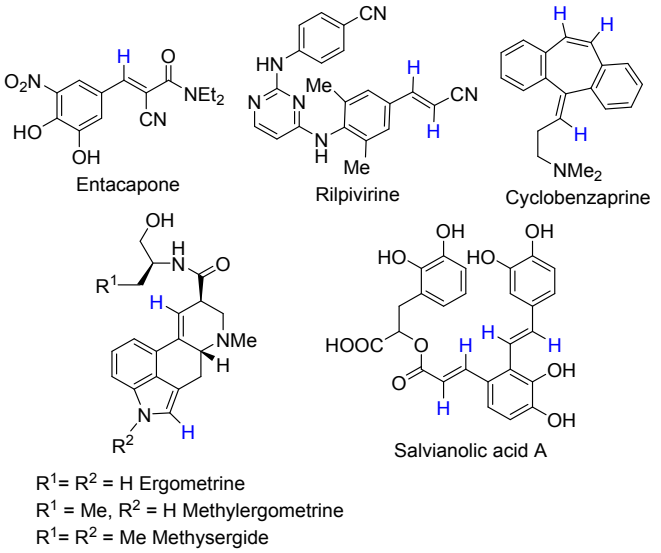

Figure 1. Examples of approved drugs and natural compounds with phenylvinyl moiety

The use of metallocatalysts meets with problems of contamination of the products resulting in a risk of the final product toxicity as well as contamination of sewage water. Formation of organolithium compounds is suitable only for alkenes with a sufficiently acidic vinyl hydrogen atom and could also affect other functional groups in the molecule. A metal-free H/D exchange of hydrogen atoms at phenylvinyl double bond using N-heterocyclic carbenes[17–20] was described a few times. The disadvantages of this method include mainly low D-enrichment and use of strong bases. In the above papers the phenylvinyl deuteration is usually applied for mechanistic studies or structure confirmation. No systematic study of such deuteration has been published.

Other methods of this double bond deuteration are based on the reduction of different groups, mainly halogen. The systematic study for halogen/deuterium exchange including few examples of phenylvinyl moiety was performed by Kuriyama et al., who used the Pd/N-heterocyclic carbene

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complexes.[21] Although this reaction affords high yields and deuterium enrichment, the use of strong bases and possible interaction of palladium catalyst with different functional groups can limit the application to other substrates. Palladium as well as many other transition metals are also known to have numerous adverse health effects[22,23] and its concentration in e.g. medical substances is strictly regulated.[24] Metal-free dehalogenation method for haloarylalkenes was also described,[25] but it required use of *hem*-diiodoalkene.

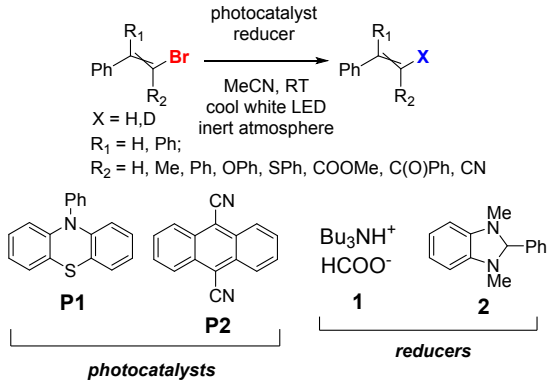
Last decade significant attention was paid to reductive dehalogenation under photoredox catalysis, however no systematic study of deuteration has ever been published. The published dehalogenation of vinyl iodides including phenylvinyl derivatives[26] used iridium-based photocatalysts. Although transition-metal photocatalysts can be replaced by different organic dyes with similar excited state reduction potential,[27–29] no studies were performed for deuteration of carbon-carbon double bond.

Herein we report a simple metal-free procedure for deuterodebromination on phenylvinyl double bond. The method can also be implemented in a reaction sequence enabling the H/D exchange on the double bond. The selective highly efficient deuterium implementation method can afford cheap and selective isotopic enrichment of such compounds for biological studies or improvement of pharmacological properties thereof.

Results and discussion

Optimization of the photoreduction system

Before the necessary synthesis of the intended D-donors, we performed the initial reactivity testing with their commercially available non-deuterated analogs (Scheme 1).



Scheme 1. Variety of screened substrates and reagents

First, we applied the published conditions for the bromoarene reduction catalyzed by 10-phenylphenothiazine (**P1**) under 380 nm LED light.[27] We subjected three bromoalkenes – β-bromostyrene (**A-Br**), 2-bromo-1,1-diphenylethylene (**B-Br**), and bromostilbene (**C-Br**) to the reaction. According to the described conditions, we used tributylamine formate (**1**) as a photoactivated H-donor (Table 1, entries 1,4, 8).

Table 1. Optimization of a photocatalyst and reducing agent.

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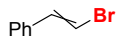
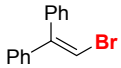
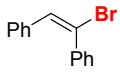
#	Substrate (Z/E ratio)	Photocatalyst	Reducing agent	Conv (NMR)
1	 **A-Br** (1:5)	**P1**[a]	5 eq **1**	8%
2		**P1**[a]	2 eq **2**	28%
3		**P2**[b]	2 eq **2**	65%
4	 **B-Br**	**P1**[a]	5 eq **1**	7%
5		**P1**[a]	2 eq **2**	73%
6		**P2**[b]	2 eq Bu_3N	19%
7		**P2**[b]	2 eq **2**	96%
8	 **C-Br** (1:13.3)	**P1**[a]	5 eq **1**	58%
9		**P1**[a]	2 eq **2**	80%
10		**P2**[b]	2 eq Bu_3N	25%
11		**P2**[b]	2 eq **2**	>99%

Conditions - acetonitrile, 5 mol% of photocatalyst, reaction time 16 h; [a] Light source 380 nm LED, 13W; [b] Light source cool white LED, 13W.

The reactions led to modest results, and only conversion of bromostilbene (**C-Br**) was significant. So, we switched to another reducing agent (H-donor) – 1,3-dimethyl-2-phenyl-benzo[d]imidazoline (**2**), which is widely known for its hydrogen atom donating properties[30,31] and is also capable of reductive coupling reactions.[32] The conversions with the reducing agent **2** were much higher (Table 1, entries 2, 5, 9).

When 9,10-dicyanoanthracene (**P2**) as a photocatalyst in combination with cool white LED irradiation was applied similarly to previously described aryl halides transformation,[28] the conversion has significantly increased. First, **P2** was used with tributylamine, as authors did, with modest success (Table 1, entries 6, 10). The pairing of **P2** with reducing agent **2** (Table 1, entries 3, 7, 11) afforded the highest conversions of all three substrates. Additional optimization data for reducing agent and light source are presented in SI (Tables S2, S3). Also, (3-butyl-1-methyl-1H-imidazol-3-ium-2-yl)borane as an alias metal-free borohydride was tested either as an only reducer (Table S2, entries 3, 9) or with a catalytic amount of **2** (entries 13-16) or 1,3-dimethyl-2-phenylbenzimidazolium iodide **[3]I** (entry 17), but without success.

The practical setup of the reaction is illustrated in Figure S1. The photoreactor can be easily constructed from commercially available laboratory washing bottle and LED strips and is suitable for carrying out of up to six analytical-scale reactions.

Having found the suitable photocatalytic system (**P2**/**2**/cool white LED), we tested reductions of several other bromoalkenes (Table 2), trying to analyse effects of different substituents on the reaction's outcome. Optimal conditions for low-reactive substrates, such as β-bromostyrene **A-Br,** 2-bromo-1-phenylpropene **D-Br**, or 1-bromo-1,2,2-triphenylethylene **E-Br,** include the addition of two portions of **P2** in 16-hour intervals (entries 1, 4, 5). The reactions of bromoalkenes **F-Br** and **G-Br** (entries 7, 8) proceeded successfully in longer reaction time. The reactions of bromophenylalkenes **B-Br**, **C-Br**, **G-Br**, **H-Br**, **I-Br,** and **J-Br** proceeded quantitatively (entries 3, 7-10). α-Bromostyrene was also tested as a substrate, but it did not undergo the reduction by the **P2**&**2** system.

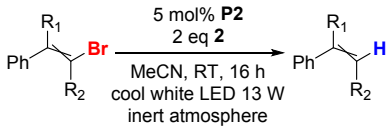


Table 2. Reductive debrominations of various substrates.

#	Br-alkene	Z-/E-	R_1	R_2	Conv (NMR)	Z-/E-
1	**A-Br**	1:5	H	H	77%[a]	-
2	**B-Br**	-	Ph	H	96%	-
3	**C-Br**	1:13	H	Ph	>99%	5.7:1
4	**D-Br**	1:7.3	H	Me	85% [a]	1:1.06
5	**E-Br**	-	Ph	Ph	70%[a]	-
6	**F-Br**	*Z*-	H	OPh	88%[b]	1:32
7	**G-Br**	1:1	H	SPh	>99%[b]	1:1.1
8	**H-Br**	1:1	H	COOMe	>99%	1:1.1
9	**I-Br**	*Z*-	H	C(O)Ph	>99%	1:19
10	**J-Br**	1.7:1	H	CN	>99%	1.8:1

[a] Two 16 h intervals, two 5% portions of **P2;** [b] Reaction time 24 h.

As the system **P2**&**2** exhibited outstanding efficiency, we tried to compare the influence of halogen atoms on reactivity. Therefore, we tested a series of chloro-, bromo- and iododerivatives of the selected alkenes (Table 3).

As we expected, chloroalkenes had lower and iodoalkenes had higher conversions into alkenes than their bromo analogs. As the alkene iodination methods are not widely available, and iodoalkenes suffer from low stability, the deuteration process using bromoalkenes seems to be the best compromise.

Arylbromides were unstable towards **P2**/**2** reducing system – in simmilar conditions as in Table 2, e. g. *p*-bromoacetophenone was debrominated by 64%, and dimethyl 2-bromoterephthalate was debrominated completely (See SI, Fig. 27, 28). So the presence of aryl halides will not be resistant to the reaction conditions.

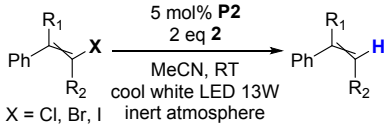


Table 3. Study of different halogen effect on photoreduction with **P2**&**2** system

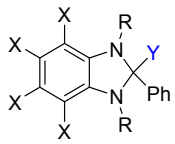
#	Structure	Halogen (Z/E)	Time	Conv (Z/E)
1	**A-**	Cl (*E*-)	16 h	15%
2		Br (1:5)		65%
3		I (*E*-)		100%
4	**B-**	Cl		50%
5		Br		96%
6	**C-**	Cl (*E*-)	4 h	35% (1.8:1)
7		Br (1:13.3)		56% (4.5:1)
8		I (*E*-)		100% (11.5:1)
9	**H-**	Cl (3.5:1)		16% (1.3:1)
10		Br (1:1)		100% (1.2:1)

Conditions - acetonitrile, 5 mol% **P2**, 2 eq **2**, 13W cool white LED.

The plausible reaction mechanism is presented at Scheme 2. The excited molecule of photocatalyst **P2*** oxidizes imidazoline **2**, affording radical cation of $\mathbf{2}^{(\cdot+)}$ – a powerful hydrogen atom donor. The excited radical anion of $[\mathbf{P2}^{(\cdot-)}]^*$ donates an electron to bromoalkene yielding vinyl radical, which quickly abstracts hydrogen from $\mathbf{2}^{(\cdot+)}$. It is worth mentioning that such an interpretation might be incomplete, since an experiment without **P2** revealed that photoreduction still proceeded at irradiation, however at a much slower rate (Table S2, entries 10, 11 in comparison to entry 5). So, the imidazoline **2**, to some extent, could work as a photoreducing agent as well. Also, by some extent the bromoalkene after its single-electron reduction can dissociate into alkenyl radical or anion. The formation of the alkenyl anion can explain the stereoselectivity in some cases or high deuterium enrichment in case of the methanol-d_4 use.

The formation of the alkenyl radical can be responsible for abstraction of the deuterium from the aprotic solvents or not complete deuteration, when methanol-d_4 was used as the solvent (see later).

At the beginning of the study of deuteration process according to Scheme 1 (X=D), we tested the efficiency of deuterated analogs of reducer **2** in various solvents. We used the 2-bromo-1,1-diphenylethylene (**B-Br**) as a model substrate, and synthesized deuterated derivatives **2-*d*** and **2-d_7** (see Fig. 2 and SI).



2: **R = Me; X = H; Y = H**
2-*d*: **R = Me; X = H; Y= D (96%D)**
2-d_7: **R = CD_3; X = H; Y = D (98%D)**
2-d_{11}: **R = CD_3; X = D; Y = D (96.8%D)**

Figure 2. Structure of reducers for Br/D exchange (see Scheme 2)

From the reaction with reducing agent **2** in CD_3CN it was shown that migration of deuterium from the solvent is less than 4% (Table S4, entry 2). Additionally, the kinetic isotope effect of the **B-Br** reduction by **2** in CD_3CN was determined as 2.61 from the competitive reactions experiment (See SI).

When monodeuterated reducer **2-*d*** was used in non-deuterated acetonitrile, the D-enrichment was significantly higher and was further increased by the application of acetonitrile-d_3 (Table S4, entry 4, 5). The application of reducer **2-d_7** in acetonitrile and CD_3CN significantly increased the conversion, and the isotopic enrichment was almost 90% in the deuterated solvent (Table S4, entry 6, 8). The deutero-debromination of **B-Br** by **2-d_7** was also tested without addition of **P2**, and despite deuterium enrichment ratio of 92.6%, the reaction rate was much slower, and after 48 h of irradiation the substrate was converted only by 75% (Table S2, entry 7).

Then, a comparative study of deuterodebromination of **B-Br** by **2-d_7** in other deuterated solvents was performed (Table S3, entries 9-12). Comparing to CD_3CN, no other solvent had better reaction conversion and D incorporation at the same time.

Some solvents as acetone-d_6 or methanol-d_4 afforded higher D-enrichment (Table S4, entries 9, 12), while DMSO-d_6 led to higher conversion (Table S4, entry 10).

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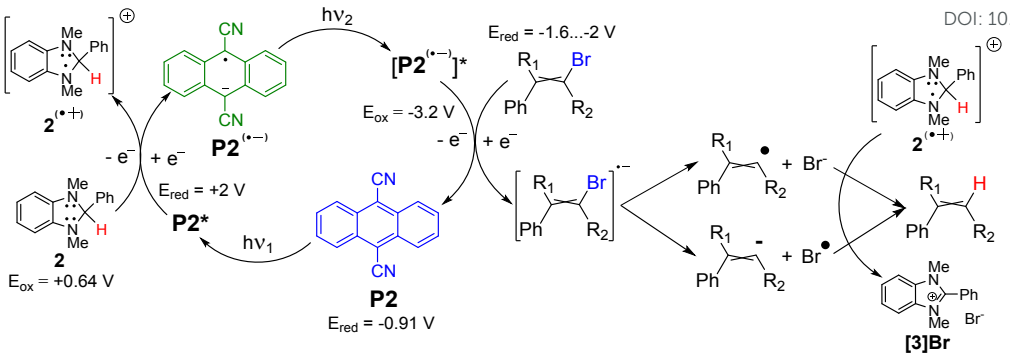


Scheme 2. Plausible phenylbromoalkene photoreduction mechanism. Electrode potentials of bromoalkenes,[33,34] reducer **2** [35] and photocatalyst **P2** [36] are recalculated vs. SCE.

Results of preparative deuterodebromination experiments

After that, **2-d_{11}** was synthesized, starting from aniline-d_5 (see SI) and used in preparative deuterodebrominations of ten bromophenylalkenes (Table 4). Comparing reductions of six substrates with **2-d_7** and **2-d_{11}** (Table S5), the more highly deuterated reducing agent provided comparable or higher D-enrichment, the conversion and yield were similar or higher. In cases when the bromine atom was sterically hindered (**E-Br**, **I-Br**), the use of **2-d_{11}** proved to be more advantageous.

Table 4. Preparative-scale deuterations.

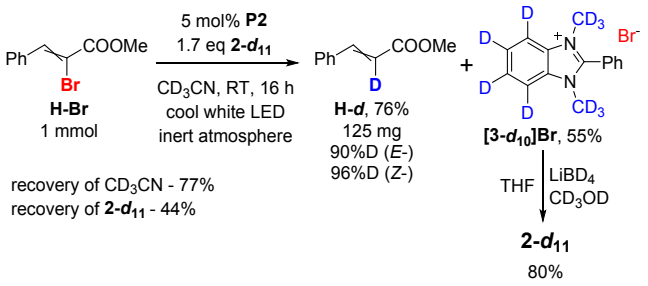
#	substrate (Z-/E-)	Conv[a] (NMR)	D content	Time	Yield[a] (Z-/E-)	**[3-d_{10}]Br** recovery
1	**A-Br** (1:5)	66%	90%	72 h[b]	58% (2.85:1)[c]	37%
2	**B-Br**	99%	93%	48 h	51%	49%
3	**C-Br** (1:13)	>99%	96%	48 h	64% (49:1)	52%
4	**D-Br** (1:7.3)	60%	77% (E) 86% (Z)	72 h[b]	56% (1.7:1)[c]	32%
5	**E-Br**	53%	77%	72 h[b]	45%[c]	40%
6	**F-Br** (*Z*-)	95%	89%	48 h[d]	94% (*E*-)	41%
7	**G-Br** (*Z*-)	>99%	67% (E) 77% (Z)	48 h[d]	84% (1:1)	55%
8	**H-Br** (1:1)	>99%	89% (E) 96% (Z)	24 h	86% (1.3:1)	41%
9	**I-Br** (*Z*-)	>99%	78%	24 h	81% (*E*-)	55%
10	**J-Br** (1.7:1)	>99%	97% (E and Z)	24 h	92% (1.78:1)	41%

For structures of the bromoderivatives see Table 1. Conditions - CD_3CN, 5 mol% **P2**, 1.7 eq **2-d_{11}**, 13W cool white LED; [a] Conversion is calculated from NMR spectra of crude reaction mixtures. The yield is calculated after isolation and purification; [b] Three 24 h intervals, three 5 mol% portions of **P2**; [c] D-alkene was isolated as a mixture with starting bromoalkene (see SI for details); [d] Two 24 h intervals, two 5 mol% portions of **P2**. (Compound **A-Br** was purchased from Sigma-Aldrich, Inc; for syntheses of other compounds see SI).

However, the higher deuteration of **2** also decreased the reaction rate, so we had to take longer reaction times for reactions with **2-d_{11}**. The reactions were monitored every 24 hours for maximum of three days.

The preparative yields vary between 45-94%. In some cases, it was not possible to fully separate the product from the starting compound (Table 4, entries 1, 4, 5). E/Z-preference was conserved in most cases during the reaction except derivatives **A-Br**, **G-Br**, and **J-Br**.

A scale-up experiment was also performed. The results – yield, reagent and solvent regeneration ratios, are exemplified at Scheme 3.



Scheme 3. High-loading deuterodebromination experiment

The precipitate of benzimidazolium bromide **[3-d_{10}]Br** formed during the reduction could be collected and reduced allowing for partial regeneration of the reducer. Thus, up to half of the used amount of **2-d_{11}** can be regenerated.

In order to analyse the influence of substituents in the phenyl ring on the reaction outcome, a series of deutero-debrominations of substituted α-bromochalcones was also performed (Table 5).

This experiment results in several implications about substituent influence. Firstly, electron-deficient substrates (**K-Br**, **L-Br**) reacted significantly slower and the reaction had to be stopped before completion, because holding it until full conversion led to partial decomposition of the reaction product. Although both substrates were used as Z-isomers, the products were formed as a mixture of E- and Z-chalcones, which could be caused by photoisomerisation of the substrate before the reduction due to lower reactivity.

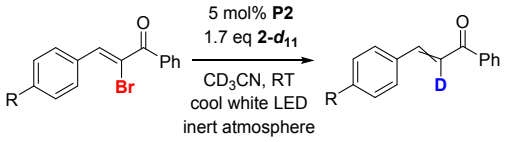


Table 5. Preparative-scale deuterations of substituted α-bromochalcones.

#	substrate (pure Z-)	R	conv (NMR)	D content	yield (Z-/E-)	[3-d_{10}]Br recovery
1	**K-Br**	NO_2	87%	65% (E) 89% (Z)	85%[a] (1.7:1)[b]	55%
2	**L-Br**	CN	75%	71% (E) 59% (Z)	89% [a] (9:1)	40%
3	**M-Br**	MeO	>99%	87%	68% (*E*-)	53%
4	**N-Br**	Me_2N	>99%	85%	24% (*E*-)	60%

Conditions - CD_3CN, 5 mol% **P2**, 1.7 eq **2-*d*$_{11}$**, 13W cool white LED, 24 h; [a] Yield considering partial regeneration of the starting compound; [b] Time of reaction 18 h.

Secondly, substrate **N-Br** despite excellent conversion to product was isolated only with the yield as low as 24%, which could be caused by partial decomposition of the reaction product as well as by interaction with silica gel during chromatography.

Regenerated **2-*d*$_{11}$** was also tested with the same six substrates that were used for comparison of **2-*d*$_7$** and **2-*d*$_{11}$** (Table 6). The screening revealed that, as in the case of **2-*d*$_7$**, only with sterically hindered substrates (**E-Br**, **I-Br**) there was a great difference in D-enrichment, so in those cases the use of recovered reducing agent may be less justified.

Additionally, NMR spectra of recovered **2-*d*$_{11}$** revealed that it had decreased deuterium enrichment in benzimidazoline aromatic positions – by 5.3 and 2.3 percent points for positions 4 and 5, respectively (see Figure 3). This could serve as an evidence that the reactive species, which are formed after debromination of **E-Br** or **I-Br**, can sometimes abstract hydrogen/deuterium competitively from aromatic positions of reducing agent 2 due to steric hindrance.

Table 6. Deuterations with regenerated **2-*d*$_{11}$** compared to the ones with new **2-*d*$_{11}$**.

#	substrate (Z-/E-)	time	conv (NMR)	D content	difference[b]	[3-d_{10}]Br recovery
1	**B-Br**	48 h	98%	87%	6	37%
2	**C-Br**	48 h	>99%	89%	7	41%
3	**E-Br**	72 h[a]	>99%	60%	17	49%
4	**H-Br**	24 h	>99%	87% (E) 95% (Z)	2 (E) 1 (Z)	52%
5	**I-Br**	24 h	>99%	58%	20	49%
6	**J-Br**	24 h	>99%	93% (E) 97% (Z)	4 (E) ≈1 (Z)	60%

Conditions - CD_3CN, 5 mol% **P2**, 1.7 eq **2-*d*$_{11}$**, 13W cool white LED; [a] Three 24 h intervals, three 5 mol% portions of **P2**; [b] Decrease in %D with recovered **2-*d*$_{11}$** compared to the reaction with a new one.

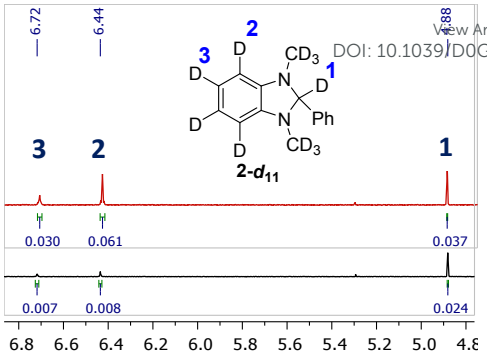


Figure 3. Compared fragments of ^{1}H NMR spectra of the **new** and **recovered** **2-*d*$_{11}$** (the integrals are normalised to phenyl protons).

That fact could, in turn, explain the dramatic decrease of enrichment and isolated yield in the reactions of **E-Br** and **I-Br** with both **2-*d*$_7$** and recovered **2-*d*$_{11}$**. Also, in the cases when two stereoisomeric D-alkenes were formed, the deuterium content in Z-deuteroalkene was usually higher, and this can also be explained by steric hindrance, because the hydrogen atom at position *2* in the molecule of reducing agent, being the most electropositive, is not the most sterically accessible one.

Economical aspects of 2-*d*$_7$/2-*d*$_{11}$ selection

We also made some calculations to compare the costs of preparation and implementation of deuterated imidazolines (see SI, p. 19). The major part of the cost being the deuterated reagents, and considering the lowest prices found by us for multigram-scale quantities, we estimated the cost of preparation as 29.5$/g for **2-*d*$_7$** and as 67.5$/g for **2-*d*$_{11}$.** The regeneration procedure lowers these prices by 20-30%, although it requires additional amounts of $NaBD_4$ and CD_3OD.

Unfortunately, for **2-*d*$_{11}$** the recovered reagent cannot be used in the reactions with sterically hindered substrates with the same efficiency as a new one (see Table 6, entries 3,5), so in these cases after regeneration **2-*d*$_{11}$** should be used with more reactive bromoalkenes. The reagent **2-*d*$_7$** can be recovered without loss of its properties.

Considering the deuterodebromination of **E-Br**, the cost of **2-*d*$_7$** and CD_3CN used is 29.3$/1 mmol of obtained D-alkene, and for **2-*d*$_{11}$** it is 59.2$/1 mmol of D-alkene. So, the first 56% of deuteration in 1 mmol of **E-*d*** is worth 0.52$ per one percent point of deuteration, and if it's needed to achieve higher enrichment, the last 21%D will come at a price of 1.42$ per one percent point. So, the average cost of deuteration of 1 mmol of **E-Br** up to 77%D will be 0.77$ per percent point of D.

For more reactive substrates, it is possible to greatly cut the costs using **2-*d*$_7$.** Thus, the deuterodebromination of **H-Br** would consume 20.45$/(mmol of **H-*d***) worth of deuterated reagents and solvents, or 0.22$ per percent point of D-enrichment (for details, see SI, p. 19). The cost could be further lowered by increase of regeneration ratio of acetonitrile-d_3, which is easier to achieve at higher scales.

So, for non-complicated and non-sterically hindered substrates the reagent of choice is in the most cases **2-*d*$_7$**, since the additional 1-5 percent points of enrichment, which the use of **2-*d*$_{11}$** could afford, would be exceptionally costly.

Environmental aspects of the reaction

The deuterodebromination reaction can be considered environmentally benign. The solvent, acetonitrile-d_3, can be easily regenerated and corresponds green chemistry principles. There is a limited amount of data about toxicity of photocatalyst **P2**, but a functionalized dicyanoantracene compound exhibited very low in vitro cytotoxicity.[37] The reducing agent **2** is reported to have quite high LD_{50} of 97 mg/kg in mice,[38] but it becomes converted into salt **[3]Br** with around 50% recovery ability. By implementation of recovery procedures, the toxic waste of the reaction can be limited to minimum amounts.

Synthesis of bromoalkenes

The starting bromoalkenes can be prepared by conventional methods from appropriate alkenes. We demonstrated this possibility on all derivatives with use of methods published in literature.[39–44] Only the derivatives **F-Br** and **G-Br** were not possible to get in sufficient yield or purity and were synthesized via substitution reactions (see SI for details).

Conclusions

A new metal-free method for light-mediated reductive debromination of phenylvinyl derivatives with the use of (poly)deuterated benzimidazoline derivatives has been developed. The reaction is possible to perform efficiently with the simple and cheap equipment. It allows the synthesis of deuterated derivatives of various substitution patterns, usually with excellent conversion and very high isotopic yield. The reducing agent can be regenerated with its recovery up to 50%. For some substrate types, it is possible to implement a sequential bromination-deuterodebromination process. The developed methodology thus offers a new environmentally benign possibility of Br/D or H/D exchange on a double bond without any special instrumental equipment.

Conflicts of interest

There are no conflicts to declare.

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