Synthesis of Fluorinated Polybrominated Diphenylethers (F-PBDEs) as Reference Standards for Environmental Analysis

Huiling Liu, Anja Skålvoll, Gaby S. Reijerink, Gregor Luthe and Jon E. Johansen
Chiron AS, Trondheim, Norway

Introduction

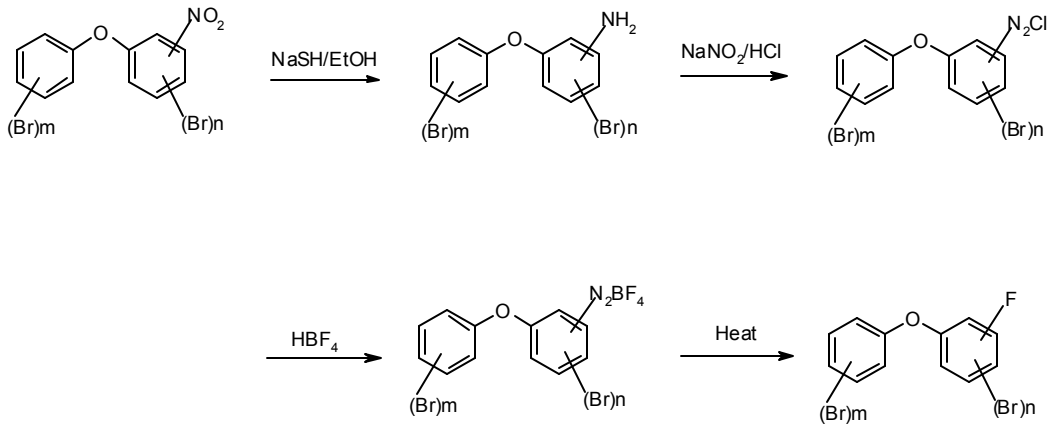
Recent focus on polybrominated diphenyl ethers (PBDEs) as possible priority pollutants has led to an increasing need for PBDE standards for analytical applications and toxicological studies. This fact has prompted Chiron AS to start a program to develop good and efficient methods of large scale PBDE synthesis for toxicological studies, as well as to search for better and more efficient internal standards for PBDE analysis. PBDE analysis is complicated due to the large number of bromine isomers, in particular for the higher brominated members. Thus, efficient PBDE analysis has been hampered by the lack of practical and cost-efficient standards.

We have previously[1] shown that mono-fluorination of PAH leads to small, but detectable differences, and that this is extremely useful in analytical contexts. This prompted us to investigate the mono- and di-fluoroPBDEs (F-PBDEs) as possible internal standards, as an alternative to more traditional and high-cost alternatives, such as the ^{13}C-labelled ones.

Materials and Methods

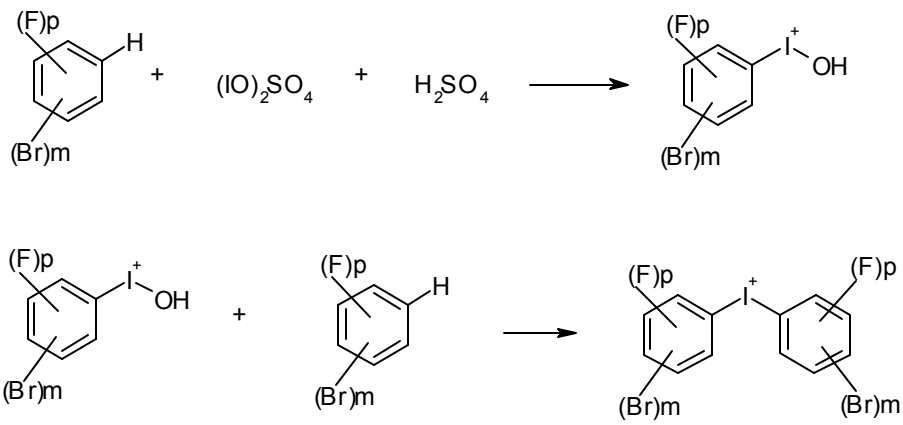
F-PBDEs were prepared either by fluorination of PBDEs or fluorination of the starting materials for making PBDEs. The fluorination substitution of PBDEs can be accomplished in different ways, for example by the Balz-Schiemann raction or by electrophilic fluorination with different agents.[2] The general procedure for Balz-Schiemann reaction of PBDEs is as follows:

Balz-Schiemann Reaction

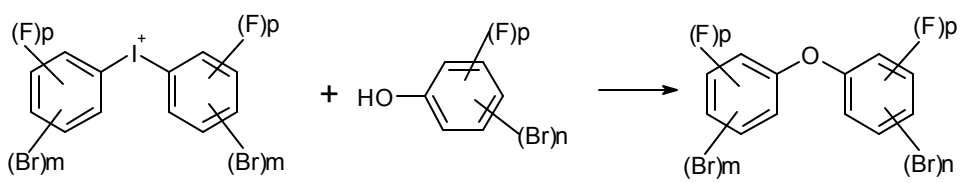


F-PBDEs can also be prepared by starting with a fluorinated starting material. Synthetic methods for pure PBDE congeners have been reported previously.[3,4] The most general one involves the coupling of an arylidonium salt with a phenol. Therefore the fluorinated starting materials could be fluorinated arylidonium salts or/and fluorinated phenols. For the non-commercial fluorinated phenols and the other fluorinated materials for making the diarylidonium salts, fluorination is also performed by using the similar procedure as mentioned above. The general procedure for the coupling reaction is shown as follows:

Diarylidonium salt:



Coulping with phenol:



(m+n = 8 – 9; p = 0 or 1)

Results and Discussion

A series of 15 F-PBDEs, which are most monofluorinated PBDEs and vary with different bromine numbers (from 1 to 9), have been synthesised by using different methods. For the F-PBDEs made from a fluorinated diarylidonium salt, the fluorine is in the *para* position in comparison to the oxygen. The reason for this is when bromofluorobenzenes are used to make the fluoro-diarylidonium salt, the iodonium ion attacks at the *para* position to fluorine atom instead of the *para* position to the bromine

substitution, because the fluorine atom has greater resonance effect than the bromine atom even though fluorine has higher electronegativity as well. For some of the F-PBDE congeners, specific methods are needed in order to get the desired isomers. Below is a list of F-PBDEs and their corresponding parent congeners made by Chiron AS.

PNDEs	**F-PBDEs**	**Structure fo F-PBDEs**	***Number of Bromine***
BDE-2	F-BDE-2	3-Bromo-4'-fluorodiphenyl ether	1
BDE-11	F-BDE-11	4-Fluoro-3,3'-dibromodiphenyl ether	2
BDE-25	F-BDE-25	4'-Fluoro-2,3',4-tribromodiphenyl ether	3
	F-BDE-27	4'-Fluoro-2,3',6-tribromodiphenyl ether	3
BDE-28	F-BDE-28	3'-Fluoro-2,4,4'-tribromodiphenyl ether	3
BDE-47	F-BDE-47	6-Fluoro-2,2',4,4'-tetrabromodiphenyl ether	4
BDE-49 BDE-66	F-BDE-66	6-Fluoro-2,3',4,4'-tetrabromodiphenyl ether	4
	F-BDE-69	4'-Fluoro-2,3',4,6-tetrabromodiphenyl ether	4
BDE-85			
BDE-99			
BDE-100	F-BDE-100	3-Fluoro-2,2',4,4',6-pentabromodiphenyl ether	5
BDE-119	F-BDE-119	3-Fluoro-2,3',4,4',6-pentabromodiphenyl ether	5
BDE-138			
BDE-153			
BDE-154	F-BDE-154	3-Fluoro-2,2',4,4',5',6-hexabromodiphenyl ether	6
BDE-183	F-BDE-160 F-BDE-183	4'-Fluoro-2,3,3',4,5,6-hexabromodiphenyl ether 3-Fluoro-2,2',4,4',5,5',6-heptabromodiphenyl ether	6 7
	Di-F-BDE-199	2,4'-Difluoro-2',3,3',4,5,5',6,6'-octabromodiphenyl ether	8
	F-BDE-208	4'-Fluoro-2,2',3,3',4,5,5',6,6'-nonabromodiphenyl ether	9

The list of the compounds covers all bromination levels up to nine. The compounds synthesized will be tested as internal standards (IS's) using GC combined with

different detection techniques, and the results will be compared with the applications of the more traditional standards, like ^{13}C-labelled ones.

The first results on the applications are encouraging and promising and will be presented in this conference as well.[5] On going studies using ^{19}F NMR and solid phase NMR will further provide information on planarity and toxicological implications.

References

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