[lit.[21] $[\alpha]^{25}_D$ -48.8° (c 2, $CHCl_3$)]; ^1H NMR 7.42-7.27 (m, 5 H), 5.52 (d, J = 4.9 Hz, 1 H), 5.50-5.40 (m, 1 H), 5.11 (s, 2 H), 4.63 (dd, J = 8.1, 2.3 Hz, 1 H), 4.36 (dd, J = 8.1, 1.6 Hz, 1 H), 4.31 (dd, J = 4.9, 2.3 Hz, 1 H), 4.11 (bd, J = 6.0 Hz, 1 H), 3.90-3.70 (m, 3 H), 1.58 (s, 3 H), 1.51 (s, 3 H), 1.43 (s, 3 H), 1.32 (s, 3 H); ^{13}C NMR 156.8, 136.8, 128.9, 128.5, 109.9, 109.3, 96.9, 71.4, 71.2, 67.1, 66.0, 61.7, 54.0, 26.0, 25.1, 24.3; IR ($CHCl_3$) 1730, 1515, 1060. Anal. Calcd for $C_{21}H_{29}NO_8$: C, 59.56; H, 6.90; N, 3.31. Found: C, 59.48; H, 6.75; N, 3.28.

For additional comparison with literature data alcohol **10** was acetylated in standard way (Ac_2O, Et_3N, DMAP cat., CH_2Cl_2, rt, 1 h), to give 1,2:3,4-di-*O*-isopropylidene-6-*N*-((carbobenzyloxy)-amino)-6-deoxy-7-*O*-acetyl-L-*glycero*-α-D-*galacto*-heptopyranose as an oil: $[\alpha]^{25}_D$ -46.9° (c 0.5, $CHCl_3$) [lit.[21] $[\alpha]^{25}_D$ -47.8° (c 2.0, $CHCl_3$)]; ^1H NMR 7.36-7.29 (m, 5 H), 5.53 (d, J = 5.0 Hz, 1 H), 5.14 (d, J = 6.04 Hz, 1 H), 5.11 (s, 2 H), 4.59 (dd, J = 7.9, 2.4 Hz, 1 H), 4.31 (dd, J = 5.0, 2.4 Hz, 1 H), 4.28-4.15 (m, 3 H), 4.25 (dd, J = 7.9, 1.7 Hz, 1 H), 3.90 (d, J = 4.3 Hz, 1 H), 2.03 (s, 3 H), 1.49 (s, 3 H), 1.38 (s, 3 H), 1.32 (s, 3 H), 1.30 (s, 3 H); ^{13}C NMR 171.0, 156.8, 137.3, 128.9, 128.5, 128.4, 110.1, 109.1, 97.0, 72.2, 71.5, 67.0, 65.9, 63.7, 51.5, 26.1, 25.1, 24.5, 20.8. IR ($CHCl_3$): 1740, 1730, 1520, 1260, 1210, 1075. Anal. Calcd for $C_{23}H_{31}NO_9$: C, 59.35; H, 6.71; N, 3.01. Found: C, 59.53; H, 6.90; N, 3.04.

2(*S*)-[1′(*S*)-((Benzyloxycarbonyl)amino)-2′-((*tert*-butyldiphenylsilyl)oxy)ethyl]-2,3-dihydro-4*H*-pyran-4-one (12). The crude adduct (see general procedure) was purified by flash chromatography (hexane–ethyl acetate, 95:5) and then treated with trifluoroacetic acid, etc. The product was crystallized (hexane–ethyl ether), affording **12** as white crystals (1.89 g, 70% yield): mp 137-139 °C; $[\alpha]^{26}_D$ -14.9° (c 1.0, $CHCl_3$); ^1H NMR 7.65-7.30 (m, 15 H), 7.21 (d, J = 6.0 Hz, 1 H), 5.41 (dd, J = 6.0, 1.0 Hz, 1 H), 5.09 (bs, 2 H), 4.87 (d, J = 9.7 Hz, 1 H), 4.76 (bd, J = 14.9 Hz, 1 H), 4.03 (m, 1 H), 3.78 (m, 2 H), 2.74 (dd, J = 16.8, 15.2 Hz, 1 H), 2.38 (dd, J = 16.8, 2.3 Hz, 1 H), 1.05 (s, 9 H); ^{13}C NMR 162.2, 135.5, 132.7, 130.0, 129.9, 128.6, 128.6, 128.3, 128.2, 127.9, 127.8, 107.5, 67.2, 62.1, 54.2, 38.8, 26.8, 19.2; IR ($CHCl_3$) 1740, 1690, 1610, 1515. Anal. Calcd for $C_{31}H_{35}NO_5Si$: C, 70.29; H, 6.66; N, 2.64. Found: C, 70.37; H, 6.64; N, 2.87.

2(*S*)-[1′(*S*)-((Benzyloxycarbonyl)amino)-2′-((*tert*-butyldiphenylsilyl)oxy)ethyl]-4(*R*)-acetoxy-2,3-dihydro-4*H*-pyran (13). Reduction of pyrone **12** (654 mg, 1.24 mmol) was accomplished in a similar manner to **7a**, yielding 656 mg (100% yield) of the crude alcohol. This oily product was dissolved in methylene chloride (10 mL). Triethylamine (0.70 mL, 505 mg, 5 mmol) followed by acetic anhydride (204 mg, 188 μL, 2 mmol) and catalytic amount of DMAP were added. After 5 min solvents were removed in vacuo. Product was purified by column chromatography (hexane–ethyl acetate, 8:2), and crystallized from hexane–ethyl ether, yielding 602 mg (85% yield) of **13** as white crystals: mp 131-132 °C; $[\alpha]^{26}_D$ -14.4° (c 1.0, $CHCl_3$); ^1H NMR 7.75-7.20 (m, 15 H), 6.36 (d, J = 6.1 Hz, 1 H), 5.58-5.38 (m, 1 H), 5.21-5.00 (m, 2 H), 4.90 (d, J = 9.7 Hz, 1 H), 4.76 (d, J = 6.1 Hz, 1 H), 4.36 (bd, J = 12.1 Hz, 1 H), 4.05-3.90 (m, 1 H), 3.75-3.60 (m, 2 H), 2.25-2.15 (m, 1 H), 2.04 (s, 3 H), 2.00-1.80 (m, 1 H), 1.06 (s, 9 H); ^{13}C NMR 145.9, 135.5, 133.0, 129.8, 129.7, 128.4, 128.0, 127.7, 127.6, 101.8, 72.2, 66.9, 65.4, 62.4, 54.6, 30.3, 26.7, 21.1, 19.1; IR ($CHCl_3$) 1740, 1730, 1655, 1510, 1250-1200. Anal. Calcd for $C_{33}H_{39}NO_6Si$: C, 69.08; H, 6.85; N, 2.44. Found: C, 69.15; H, 6.83; N, 2.43.

7-((*tert*-Butyldiphenylsilyl)oxy)-6(*S*)-((benzyloxycarbonyl)amino)-5(*S*)-hydroxy-2-heptenal (14). Acetate **13** (571 mg, 1.0 mmol) was dissolved in dioxane (50 mL). Sulfuric acid (200 mL, 0.005 M aqueous H_2SO_4) and mercury(II) sulfate (592 mg, 2 mmol) were added, and the reaction mixture was virogously stirred for 48 h. Then sodium bicarbonate (252 mg, 3 mmol) was added, and after 10 min the product was extracted with diethyl ether (3 × 200 mL). Combined extracts were washed with brine, dried ($MgSO_4$), and evaporated to give 475 mg (90% yield) of the crude unstable aldehyde **14**, which was immediately used in the next transformation: ^1H NMR 9.51 (d, J = 7.9 Hz, 1 H), 7.67-7.28 (m, 15 H), 6.88 (dt, J = 15.9, 6.8 Hz, 1 H), 6.16 (dd, J = 15.9, 7.9 Hz, 1 H), 5.14 (d, J = 9.4 Hz, 1 H), 5.09 (m, 2 H), 4.16 (bt, J = 5.6 Hz, 1 H), 3.89-3.80 (m, 2 H), 3.72-3.67 (m, 1 H), 3.12 (bs, 1 H), 2.58-2.42 (m, 2 H), 1.06 (s, 9 H).

7-((*tert*-Butyldiphenylsilyl)oxy)-6(*S*)-((benzyloxycarbonyl)amino)-5(*S*)-hydroxy-2-heptenoic Acid, Methyl Ester (15). Aldehyde **14** (475 mg, 0.9 mmol) was dissolved in methanol (100 mL), and sodium cyanide (220.5 mg, 4.5 mmol) was added. When the salt dissolved, acetic acid (120 mg, 114 μL, 2 mmol) and active manganese(IV) oxide (2.0 g, 23 mmol) were added. Oxidation was carried out for 2 days. Then the reaction mixture was filtered through Celite (solid washed with methanol) and evaporated. The oily residue was partitioned between water (50 mL) and ethyl ether (150 mL). The organic layer was washed with brine (50 mL), dried ($MgSO_4$), and evaporated. The main product was separated by column chromatography (hexane–ethyl acetate, 7:3), affording 280-393 mg (50-70% yield, depending on MnO_2 activity) of ester **15** as an oil: $[\alpha]_D^{25}$ +2.5° (c 1.0, $CHCl_3$); ^1H NMR 7.70-7.25 (m, 15 H), 6.97 (dt, J = 15.6, 7.2 Hz, 1 H), 5.89 (d, J = 15.7 Hz, 1 H), 5.40 (d, J = 9.1 Hz, 1 H), 5.09 (s, 2 H), 4.12 (bt, J = 5.9 Hz, 1 H), 3.87-3.79 (m, 2 H), 3.72 (s, 3 H), 3.72-3.65 (m, 1 H), 3.01 (bs, 1 H), 2.46-2.29 (m, 2 H), 1.05 (s, 9 H); ^{13}C NMR 170.3, 156.4, 144.8, 136.4, 135.5, 132.4, 130.2, 128.6, 128.2, 128.1, 128.0, 123.6, 71.4, 67.0, 66.4, 54.3, 51.5, 36.9, 26.9, 19.2; IR ($CHCl_3$) 1730, 1715, 1660, 1500, 1200. Anal. Calcd for $C_{32}H_{39}NO_6Si$: C, 68.42; H, 7.00; N, 2.49. Found: C, 68.32; H, 7.03; N, 2.44.

***N*-(Benzyloxycarbonyl)anhydrogalantinic Acid Methyl Ester (17) and C3 Epimer 16.** Ester **15** (143 mg, 0.255 mmol) was dissolved in 4 mL of THF, and then tetrabutylammonium fluoride (0.5 mL of 1.0 M solution in THF, 0.5 mmol) was added. After 15 min of stirring the solvent was evaporated and the residue was dissolved in 25 mL of methanol. Then anhydrous potassium carbonate (7 mg, 0.05 mmol) was added, and after 15 h of stirring, solvent was evaporated and two diastereoisomers were separated giving 31 mg of ester **17** and 30 mg of C3 epimer (75% total yield).

16: mp 123-124 °C; $[\alpha]^{20}_D$ +12.4° (c 2.5, $CHCl_3$); ^1H NMR 7.40-7.30 (m, 5 H), 5.43 (bd, J = 7.3 Hz, 1 H), 5.13-5.05 (m, 2 H), 4.21-4.15 (m, 1 H), 4.07 (bs, 1 H), 3.68 (s, 3 H), 3.67 (m, 1 H), 3.55 (bd, J = 6.7 Hz, 1 H), 2.58 (m, 1 H), 2.47 (dd, J = 15.2, 8.1 Hz, 1 H), 2.38 (dd, J = 15.5, 4.8 Hz, 1 H), 1.80-1.60 (m, 2 H); ^{13}C NMR 171.4, 156.0, 136.2, 128.6, 128.2, 69.1, 67.0, 66.2, 65.5, 51.9, 50.3, 40.9, 33.8; IR ($CHCl_3$) 1730, 1510, 1205, 1060. Anal. Calcd for $C_{16}H_{21}NO_6$: C, 59.43; H, 6.55; N, 4.33. Found: C, 59.43; H, 6.67; N, 4.23.

17: mp 126-127 °C; $[\alpha]^{22}_D$ +2.6° (c 1.1, $CHCl_3$); ^1H NMR 7.40-7.30 (m, 5 H), 5.11 (s, 2 H), 4.65 (bs, 1 H), 4.05 (dd, J = 11.3, 4.6 Hz, 1 H), 3.84-3.78 (m, 1 H), 3.69 (s, 3 H), 3.50-3.60 (m, 2 H), 3.11 (bt, J = 10.5 Hz, 1 H), 2.80 (bs, 1 H), 2.60 (dd, J = 15.6, 7.9 Hz, 1 H), 2.45 (dd, J = 15.5, 5.1 Hz, 1 H), 2.12 (ddd, J = 12.8, 4.4, 1.9 Hz, 1 H), 1.44 (dd, J = 23.8, 11.2 Hz, 2 H); ^{13}C NMR 171.3, 157.1, 136.0, 128.7, 128.4, 128.3, 72.9, 71.9, 68.4, 67.4, 54.6, 51.9, 40.4, 39.2; IR ($CHCl_3$) 1735, 1510, 1210, 1065. Anal. Calcd for $C_{16}H_{21}NO_6$: C, 59.43; H, 6.55; N, 4.33. Found: C, 59.51; H, 6.52; N, 4.39.

For correlation reason compound **17** was transformed into NH-BOC form: mp 108-109 °C; $[\alpha]^{26}_D$ -5.4° (c 0.8, $CHCl_3$) [lit.[25] mp 104.5-106 °C; $[\alpha]^{26}_D$ -4.4° (c 1.2, $CHCl_3$)].

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Mild Fluorofunctionalization of Side Chains in Alkyl-Substituted Aromatics by Cesium Fluoroxysulfate

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The side-chain functionalization of alkyl groups, observed in a variety of reactions involving alkyl-substituted aromatic derivatives, has remained so far an open problem from the synthetic as well as mechanistic point of view,[1-6]

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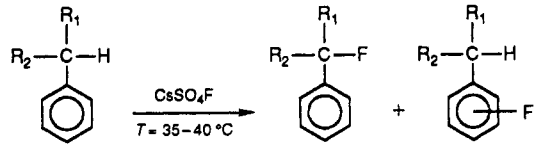
Table I. Fluorination of Alkyl-Substituted Benzenes with $CsSO_4F$



1 2 3

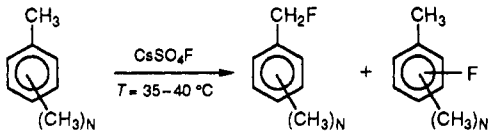
substrate (1)	solvent	rel distrib[a] chain (2)	rel distrib[a] ring (3)	yield[b] (%)
1a: $R_1 = R_2 = H$	CH_3CN	90	10	68
1b: $R_1 = H$, $R_2 = CH_3$	CH_3CN	100	traces	73
1c: $R_1 = R_2 = CH_3$	CH_3CN	100	traces	70
	CH_3CN/O_2	traces	100	12
1d: $R_1 = H$, $R_2 =$ Ph	CH_3CN	85	15	70
	CH_3CN/O_2	25	75	20
1e: $R_1 = R_2 =$ Ph	CH_3CN	100	traces	70

[a] 1 mmol of substrate and 1.6 mmol of $CsSO_4F$ in 2 mL of dry solvent, inert atmosphere, 1 h; determined by ^{19}F NMR. [b] Determined by ^{19}F NMR using octafluoronaphthalene as internal standard and calculated on starting material.

although recently Kochi and co-workers made an important contribution in elucidating the course of functionalization of alkyl-substituted aromatics.[7]

Direct side-chain fluorofunctionalization is observed only in a few cases of fluorination of alkyl-substituted aromatics. The course of the fluorination of toluene with elemental fluorine[8] is strongly temperature dependent, and the side chain fluorofunctionalization becomes more pronounced with increased reaction temperature. Almost the opposite process is observed in fluorinations with acetyl hypofluorite at room temperature,[9] while no side-chain fluorofunctionalization occurs when *N*-fluoro-N-bis(trifluoromethyl)sulfonimide[10] or xenon difluoride[11] are used as the fluorinating reagents. On the other hand, Appelman and co-worker[12] reported that fluorination with cesium fluoroxysulfate ($CsSO_4F$) in acetonitrile solution results, almost regiospecifically, in side-chain fluorofunctionalization, while only ring fluorination is observed in the BF_3-catalyzed reaction.[13]

Table II. Fluorination of Methyl-Substituted Benzenes with $CsSO_4F$



4 5 6

substrate (4)	solvent	rel distrib[a] chain (5)	rel distrib[a] ring (6)	yield[b] (%)
4a: *o*-xylene	CH_3CN	90	10[c]	76
4b: *m*-xylene	CH_3CN	62	38[d]	75
	CH_3CN/CH_2Cl_2, 1:1	36	64	63
	CH_3CN/CH_2Cl_2, 1:9	32	68	50
	CH_2Cl_2	–	traces	<2
	$CH_3CN/PhNO_2$[e]	50	50	72
	CH_3CN/O_2[f]	37	63	68
4c: *p*-xylene	CH_3CN	90	10[g]	75
	CH_3CN/CH_2Cl_2, 4:1	87	13	70
	CH_3CN/CH_2Cl_2, 1:1	73	27	53
	CH_2Cl_2	–	traces	<2
	CH_3CN/O_2	58	42	42
4d: 1,2,3-trimethylbenzene	CH_3CN	90[h]	10[i]	75
4e: 1,2,4-trimethylbenzene	CH_3CN	85[j]	15[k]	74
	CH_3CN/O_2	63[l]	37	73
4f: 1,3,5-trimethylbenzene	CH_3CN	38	62	75
	$CH_3CN/PhNO_2$	33	67	70
	CH_3CN/O_2	32	68	70

[a] 1 mmol of substrate and 1.6 mmol of $CsSO_4F$ in 2 mL of dry solvent, inert atmosphere, T = 35–40 °C, 1 h; determined by ^{19}F NMR. [b] Determined by ^{19}F NMR using octafluoronaphthalene as internal standard and calculated on starting material. [c] 3- and 4-fluoro-1,2-dimethylbenzene in 1:1 ratio. [d] 2- and 4-fluoro-1,3-dimethylbenzene in 1:2 ratio. [e] 0.5 mmol of $PhNO_2$. [f] 2 mL of CH_3CN saturated with O_2. [g] 2-Fluoro-1,4-dimethylbenzene. [h] 2,3- and 2,6-dimethylbenzyl fluoride in 2:1 ratio. [i] 4-Fluoro-1,2,3-trimethylbenzene. [j] 3,4-, 2,4-, and 2,5-dimethylbenzyl fluoride in 1:1.2:1 ratio. [k] 3- and 5-fluoro-1,2,4-trimethylbenzene in 1:1 ratio. [l] 3,4-, 2,4-, and 2,5-dimethylbenzyl fluoride in 1:0.3:1 ratio.

A limited number of reagents[14-16] are suitable for direct fluorination of organic molecules under mild reaction conditions. XeF_2 and $CsSO_4F$ are two of them, but their reactivities differ markedly.[17-19] The well-known fact that only a small structural change in organic molecule can drastically change the reaction course motivated us to study the effect of the structure of the alkyl-substituted

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aromatic molecules on their reactions with $CsSO_4F$.

Results and Discussion

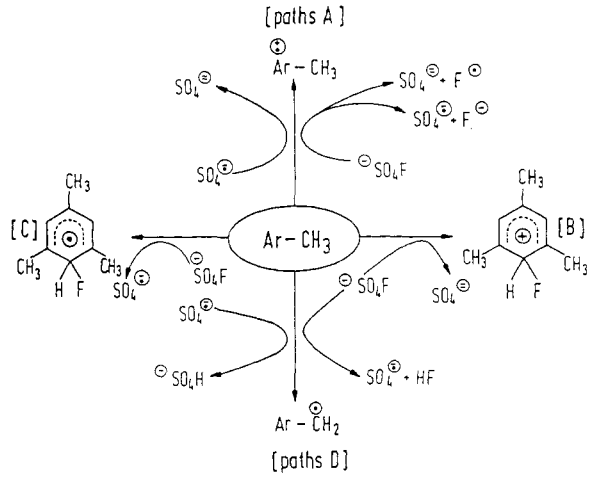
The reactions of $CsSO_4F$ with monosubstituted alkylbenzenes were investigated first. The highest conversions of starting material to fluoro-substituted products (70–80% based on internal standard) were achieved when 0.5 molar acetonitrile solutions of alkyl-substituted aromatic derivatives were treated with 60% molar excess of $CsSO_4F$. The use of stoichiometric amounts of the reagent gave lower conversions of starting material, while a larger molar excess improved the conversions of starting material, but not the selectivity of the reaction, thus producing considerable amounts of over-fluorinated products or even polymeric material. As shown in Table I, the side-chain fluorofunctionalization of alkyl-monosubstituted benzene derivatives (**1a–e**) was highly predominant, if not an exclusive process. Only in the case of toluene and diphenylmethane was up to 15% of ring fluorination observed. The presence of oxygen, often used as a radical scavenger, considerably affected the reaction, and in addition to the dramatic reduction of starting material conversion, inhibition of side-chain fluorination was noticed when isopropylbenzene or diphenylmethane was treated with $CsSO_4F$ in O_2-saturated CH_3CN.

We also studied the fluorination of di- and trimethyl-substituted benzenes (**4a–f**, Table II) and the effects of the substrate structure, solvent, and the presence of O_2 or $PhNO_2$ on the reaction course (see Table II). In all but two studied substrates, the benzylic fluorofunctionalization was a highly predominant process. *o*- and *p*-xylene were readily converted to their fluoromethyl derivatives (**5a, 5c**), as well as 1,2,3-trimethylbenzene, where both fluoromethyl isomers (**5d**) were formed in 2:1 ratio, and 1,2,4-trimethylbenzene, where all three fluoromethyl isomers, i.e 3,4-, 2,4-, and 2,5-dimethylbenzyl fluoride (**5e**), in 1:1.2:1 relative ratio were detected. On the other hand, fluorination of *m*-xylene gave 38% of ring-fluorinated products, while in the case of 1,3,5-trimethylbenzene, ring fluorofunctionalization (68%) became predominant. As is evident from Table II, the solvent polarity, modulated by CH_2Cl_2 addition, and the presence of O_2 also considerably influenced the fluorination of *m*- and *p*-xylene, where by lowering the solvent polarity, ring fluorination became more pronounced, while overall yields of fluorinated products were diminished. A similar effect was established when O_2-saturated CH_3CN was used as solvent, while following the reaction in pure CH_2Cl_2 only small amounts of fluorinated products could be detected. O_2 had a neglible effect on the fluorination of 1,3,5-trimethylbenzene, while a small inhibition of chain fluorofunctionalization was established in the case of 1,2,4-trimethylbenzene.

Finally, we studied the effect of the aromatic nucleus structure on the extent of side-chain versus ring fluorofunctionalization and found that 1-methylnaphthalene yielded 1-(fluoromethyl)naphthalene in 50% relative yield, the ring fluorination being unselective, while 2-methylnaphthalene gave 1-fluoro-2-methylnaphthalene and 2-(fluoromethyl)naphthalene in 2:1 ratio.

According to our experience, expressed in this paper and our previous work,[20] optimal yields of fluorinated products as well as the conversions of starting material are obtained when the fluorination of an organic substrate is carried out in a suspension of $CsSO_4F$ in an appropriate solvent. When the reaction of methyl-substituted benzenes was performed in a CH_3CN solution of $CsSO_4F$, only 30% of the starting material was consumed, and no more than 25% of the fluorinated products were formed. Therefore, an important factor which must be taken into account in the explanation of the course of the reactions of $CsSO_4F$ with organic molecules is its low solubility in organic solvents.[12b] It is not clear whether the reactions proceed in the liquid phase, on the surface, or near the surface, and even the very large cesium ionic radius can play a significant role.[21] Four different species which can be formed by different ways and can make different contributions to the fluorofunctionalization of alkyl-substituted aromatic molecules are presented in Scheme I. An aromatic molecule can be transformed to the ion radical in at least three different ways (paths A): through the formation of SO_4^{2-} and $F^{\bullet}$, or through $SO_4^{\bullet-}$ and F^-, while the third reasonable way is the reaction between the organic molecule and $SO_4^{\bullet-}$. The formation of ion radical is very likely because $CsSO_4F$ is a strong oxidant.[22] It has been already demonstrated that alkyl-substituted aromatic molecules reacted with $S_2O_8^{2-}$, also a strong oxidizer like $CsSO_4F$, thus forming a cation radical[23] which was, after further abstraction of proton, transformed into a radical intermediate, and the reaction resulted in side-chain functionalization.[24] The reaction with $CsSO_4F$ can also result in the formation of cationic intermediate (path B) or radical intermediate (path C). Direct conversion of the aromatic molecule to a side-chain radical (paths D) by $CsSO_4F$ or $SO_4^{\bullet-}$ could also not be excluded.

Scheme I



From the results presented, it is evident that at least two main processes are involved in the reactions of alkyl aromatics with $CsSO_4F$. Reactions with alkyl monosubstituted derivatives **1a–e** proceed mainly through radical intermediates, while for the ring fluorofunctionalization, as evident from already published results,[12b,13] predominantly ionic intermediates were proposed. Side chain fluorinated products could also be formed through ionic intermediates after an ipso attack by $CsSO_4F$. This can not be neglected in the fluorination of di- and trimethyl-substituted benzenes **4a–f**, so that both processes, radical and ionic, compete significantly in this case.

The presented study shows that in the side-chain fluorofunctionalization with $CsSO_4F$ several processes compete,

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and it is very difficult to make a clear-cut distinction among them. Nevertheless, the total difference among the reactivities of $CsSO_4F$ and other fluorinating agents with methyl-substituted benzene derivatives has been demonstrated, with $CsSO_4F$ as a unique reagent for the direct fluorosubstitution of benzylic hydrogen showing reasonable to excellent selectivity and yield.

Experimental Section

^1H and ^{19}F NMR spectra were recorded at 60 and 56.45 MHz, respectively. Chemical shifts are expressed in ppm from Me_4Si or CCl_3F as internal standards. TLC was carried out on Merck PCS-Fertigplatten Silicagel F-254. Alkyl aromatics from commercial sources were used, and $CsSO_4F$ was prepared according to the literature[12,20] and handled and stored in compliance with applicable instructions[20].

Fluorination of Alkyl-Substituted Aromatics with $CsSO_4F$. General Procedure. A solution of 1 mmol of alkyl-substituted aromatic substrate in 2 mL of freshly distilled and dry CH_3CN was degassed with dry oxygen-free N_2. Then 400 mg (1.6 mmol) of $CsSO_4F$ was introduced, and the reaction mixture was stirred under N_2 at 35–40 °C for 1 h and diluted with 20 mL of CH_2Cl_2. The insoluble residue was filtered off. The filtrate was washed with 20 mL of water, dried (Na_2SO_4), and evaporated under reduced pressure. The crude reaction mixtures were analyzed by GLC and ^1H and ^{19}F NMR spectroscopy. The amounts of the fluorinated products formed were determined from ^{19}F NMR spectra of the crude reaction mixtures using octafluoronaphthalene as internal standard. Products were isolated by preparative GLC (DNP 10%, Chromosorb W A/W 80/100) or TLC and identified on the basis of the spectroscopical data and comparison with literature and in some cases also by conversion to known compounds.

Benzyl fluoride[25] **(2a)**: 70%, liquid. **1-Fluoro-1-phenylethane**[26] **(2b)**: 73%, converted to styrene. **2-Fluoro-2-phenylpropane**[26] **(2c)**: 70.5%, converted to α-methylstyrene. **Fluorodiphenylmethane**[26] **(2d)**: TLC, 54%, oily. **Fluorotriphenylmethane**[26] **(2e)**: TLC, 55.3%, mp 102–103 °C, mp[27] 103–104 °C. **2-Methylbenzyl fluoride**[28] **(5a)**: GLC, 36%, liquid. **3-Methylbenzyl fluoride**[25] **(5b)**: GLC, 24%, liquid. **4-Methylbenzyl fluoride**[25] **(5c)**: TLC, 66%, liquid. **1-(Fluoromethyl)naphthalene**:[29] TLC, 35%, oily. **2-(Fluoromethyl)naphthalene**:[29] TLC, 22%, mp 52–53 °C. **1-Fluoro-2-methylnaphthalene**:[30] TLC, 45.5%, oily.

3,5-Dimethylbenzyl fluoride (5f): GLC, 18%, liquid; NMR (CCl_4) δ_F −210.3 (t, J = 47 Hz), δ_H 2.3 (s, 6 H), δ_H 5.2 (d, J = 47 Hz, 2 H), δ_H 7.0 (m, 3 H); HRMS calcd for $C_9H_{11}F$ m/z 138.0844, found m/z 138.0845; MS m/z 138 (M, 100), 137 (20), 123 (95), 105 (25), 91 (10).

2,3-Dimethylbenzyl fluoride and 2,6-dimethylbenzyl fluoride[31] **(5d, 2:1 mixture)**: TLC, 54%, liquid; NMR (CCl_4) δ_F −210.0 (t, $^2J_{FH}$ = 47 Hz), δ_H 2.2–2.4 (m, 6 H), δ_H 5.3 (d, J = 47 Hz, 2 H), δ_H 7.1 (m, 3 H), and δ_F −211.5 (t, $^2J_{FH}$ = 47 Hz), δ_H 2.2–2.4 (m, 6 H), δ_H 5.4 (d, J = 47 Hz, 2 H), δ_H 7.0 (m, 3 H); HRMS calcd for $C_9H_{11}F$ m/z 138.0844, found m/z 138.0850; MS m/z 138 (M^+, 90), 137 (25), 123 (100), 105 (80), 91 (20), 77 (20). **3,4-Dimethylbenzyl fluoride,**[25] **2,4-dimethylbenzyl fluoride,**[25] **and 2,5-dimethylbenzyl fluoride**[25] **(6e, 1:0.5:1 mixture)**: TLC, 51%, liquid; NMR (CCl_4) δ_F −204.0, 206.5, and 209.3 (t, J_{FH} = 47 Hz); MS m/z 138 (M^+, 75), 137 (25), 123 (100), 105 (75), 91 (20), 77 (20).

Fluorination of Alkyl-Substituted Aromatics with $CsSO_4F$ in the Presence of Oxygen. A solution of 1 mmol of alkyl-substituted aromatic substrate in 2 mL of dry CH_3CN was saturated with dry oxygen. $CsSO_4F$ (400 mg, 1.6 mmol) was added, and the reaction mixture was stirred under O_2 at 35–45 °C for 1 h. After the usual workup procedure, the crude reaction mixtures were analyzed by ^{19}F NMR. The distributions of the products are presented in Table II.

Registry No. **1a**, 108-88-3; **1b**, 100-41-4; **1c**, 98-82-8; **1d**, 101-81-5; **1e**, 519-73-3; **2a**, 350-50-5; **2b**, 7100-97-2; **2c**, 74185-81-2; **2d**, 579-55-5; **2e**, 427-36-1; **4a**, 95-47-6; **4b**, 108-38-3; **4c**, 106-42-3; **4d**, 526-73-8; **4e**, 95-63-6; **4f**, 108-67-8; **5a**, 62037-88-1; **5b**, 456-44-0; **5c**, 459-50-7; **5f**, 136822-77-0; **6e**, 52547-99-6; **6f**, 392-69-8; $CsSO_4F$, 70806-67-6; 2,3-dimethylbenzyl fluoride, 117455-55-7; 2,6-dimethylbenzyl fluoride, 62037-90-5; 3,4-dimethylbenzyl fluoride, 75787-75-6; 2,4-dimethylbenzyl fluoride, 75787-74-5; 2,5-dimethylbenzyl fluoride, 136822-78-1; 2-(fluoromethyl)naphthalene, 55831-11-3; 1-fluoro-2-methylnaphthalene, 573-99-9; 1-(fluoromethyl)naphthalene, 55831-10-2; 3-fluoro-1,2-dimethylbenzene, 443-82-3; 4-fluoro-1,2-dimethylbenzene, 452-64-2; 2-fluoro-1,3-dimethylbenzene, 443-88-9; 4-fluoro-1,3-dimethylbenzene, 452-65-3; 2-fluoro-1,4-dimethylbenzene, 696-01-5; 3-fluoro-1,2,4-trimethylbenzene, 26630-72-8; 5-fluoro-1,2,4-trimethylbenzene, 400-01-1.

Supplementary Material Available: ^1H and ^{19}F NMR spectra of compound **5f** (2 pages). Ordering information is given on any current masthead page.

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Nucleophilic Aromatic Substitution by Hydroxide Ion under Phase-Transfer Catalysis Conditions: Fluorine Displacement in Polyfluorobenzene Derivatives

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Nucleophilic aromatic substitution reactions can be conveniently performed under phase-transfer catalysis conditions (PTC).[2] A few examples for the generality of this technique are the formation of aryl sulfides in activated aromatic rings by catalysis of ammonium and phosphonium salts,[3,4] aryl alkyl ethers by catalysis of poly(ethylene glycols),[5] and phenylalkyl nitriles by catalysis of ammonium salts.[6] The application of alkylpyridinium salts as phase-transfer catalysts affords aromatic nucleophilic substitution reactions at high temperatures[7] while activation by complexes of transition metals affords a high yield even at low temperatures.[8] The role of the base in these reactions is to form the active nucleophile, e.g., alkoxide, thiolate, etc. However, there are no examples of direct nucleophilic aromatic substitutions with hydroxide ion under PTC conditions. This can be rationalized by the expectation that the hydration sphere that surrounds the hydroxide ion would cause a decrease in the hydroxide's nucleophilicity.[9] In recent years a growing number

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