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Halogenation of ketones with *N*-halosuccinimides under solvent-free reaction conditions

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ABSTRACT

Several aryl substituted ketones, cyclic ketones, 1,3-diketones and a β-ketoamide were halogenated with *N*-halosuccinimides under solvent-free reaction conditions (SFRC) at various temperatures (20–80 °C), whereas less enolized ketones required the presence of an acid catalyst (*p*-toluenesulfonic acid, PTSA). Bromination of substituted acetophenones obeys first order kinetics $v=k_{Br}$[ketone] and the following correlation with the keto–enol equilibrium constant: $\log k_{Br}=0.3pK_E+C_1$, less enolized substrates being more reactive; the moderate positive charge developed in the rate determining step was confirmed by the Hammett correlation ($\rho=-0.5$). On the other hand, in cyclic ketones an opposite relation was observed: $\log k_{Br}=-0.6pK_E+C_2$, indicating higher reactivity of substrates with higher enolization constant (K_E). The important role of the nature of the solvent (MeCN, MeOH) in preorganization of the ketone–NBS–PTSA mixture prior to SFRC bromination was found.

1. Introduction

Demands for sustainable and ecologically friendly organic syntheses[2] are stimulating the search for alternatives to the use of organic solvents in synthetic reactions. Performing reactions under solvent-free reaction conditions (SFRC) is an important and interesting alternative, but reaction pathways, as well as the products formed, can be modified significantly.[3,4]

N-Halosuccinimides represent an important class of halogenating reagents,[5] among which *N*-bromosuccinimide (NBS) is widely used; transformations can be modulated with various reaction conditions (catalysts,[6] solvents,[7] mediators[8] and SFRC[9]). Aryl substituted ketones, possessing two potential donor sites, are very sensitive model compounds and the important role of the solvent on the regioselectivity of electrophilic functionalization was already reported.[5,10] Two reaction pathways have been observed in bromination of acetophenones: a positive Hammett ρ value was observed in functionalization with deprotonation and development of a negative charge at the α position as the dominant process (Scheme 1, case B), while a negative ρ value was observed in acid-catalyzed functionalization with the development of positive charge (case A).[10] The conjugation of electrons between the methoxy and carbonyl group in *p*-methoxy acetophenone makes the phenyl ring and the molecule as a whole very sensitive to reaction conditions and an excellent model substrate,[11] resulting in different regioselectivity of functionalization, i.e., ring versus side chain substitution. The important role of the solvent on the regioselectivity of *p*-methoxy acetophenone has been demonstrated several times in various halogenations.[1,12]

We now wish to report our investigations of the effect of the structure of *N*-halosuccinimides, the influence of catalyst, reaction temperature and the aggregate state of the substrates on the halogenation of ketones under SFRC, a continuation of our preliminary communication.[1] Because of the lack of quantitative information on transformations under SFRC, the effect of ketone structure and reaction conditions on bromination was evaluated kinetically, while the Hammett correlation offered further insight into the nature of side chain bromination (Scheme 1).

2. Results and discussion

Acetophenone was used as a target molecule in evaluation of various halogenating agents with respect to mono versus disubstitution, oxidation or ring functionalization in several studies.[5,10] Bromination with NBS depends on the catalyst used and it has also been confirmed recently that photo initiated transformation in diethyl ether gave a high yield of mono brominated products.[13]

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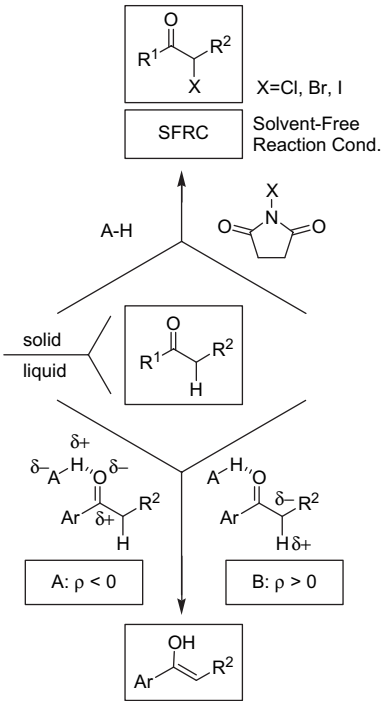
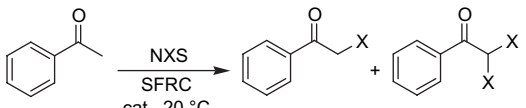


Scheme 1.

First, we studied the effect of the *N*-halosuccinimide (NXS) structure on the halogenation of acetophenone (**1**) under SFRC. Room temperature reaction in the absence of a catalyst was not successful (entries 1, 3 and 5), while in the presence of 0.1 mmol of *p*-toluenesulfonic acid (PTSA) immediate bromination was observed with 95% conversion to **2b** after 3 h (Table 1, entry 2). A similar reaction with *N*-chlorosuccinimide (NCS) in the presence of PTSA gave a much lower conversion after 3 h, but could be enhanced by prolonged reaction times and resulted in 84% conversion after 24 h. However, lower selectivity was observed and monochlorinated derivative **2a** was accompanied by 6% of 2,2-dichloro-1-phenylethanone-1-one (**3a**, entry 4). High conversion was also observed for iodination with *N*-iodosuccinimide (NIS), where monoiodo product **2c** was formed selectively (entry 6).

In contrast to acetophenones, β-diketones, β-keto esters and β-keto amides have a higher degree of enolization, which is also reflected in their halogenation under SFRC. No catalyst was

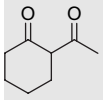
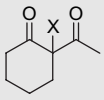
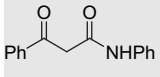
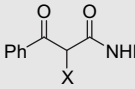
Table 1
The effect of reagent and catalyst on halofunctionalisation[a] of acetophenone (**1**)



Entry	NXS	Cat.	*T* [h]	Conv. [%]	Selectivity **2**:**3**
1	NBS	—	24	19	1:0
2		PTSA	3	95	1:0
3	NCS	—	24	—	
4		PTSA	24	90	15:1
5	NIS	—	24	—	
6		PTSA	24	81	1:0

[a] Reaction conditions: 1 mmol of ketone **1**, 1 mmol of NXS, cat. (0.1 mmol of PTSA), conversion determined by NMR.

Table 2
SFRC halogenation of 2-acetylcyclohexanone (**4**, liquid) and 3-oxo-3,*N*-diphenylpropionamide (**6**, solid) with *N*-halosuccinimides

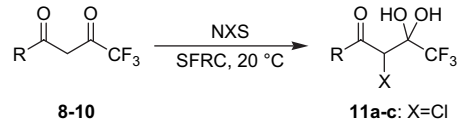
Substrate		Reagent[a]	Product		Yield [%]
	**4**	NCS NBS NIS		**5a** (X=Cl) **5b** (X=Br) **5c** (X=I)	95 98 72
	**6**	NCS NBS NIS		**7a** (X=Cl) **7b** (X=Br) **7c** (X=I)	67 85 83

[a] Reaction cond.: 1 mmol of substrate; 1 mmol of NXS; SFRC, 20 °C; reaction time: **5a**,**c** and **7**, 3 h; **5b**, 1 h.

required for transformation of liquid 2-acetylcyclohexanone (**4**) and after 1 h at room temperature, brominated derivative **5b** was formed in quantitative yield (Table 2). Iodination and chlorination also proceeded without the presence of a catalyst, while a longer reaction time (3 h) was required for complete conversion with an excellent yield of chlorinated derivative **5a**. Iodination did not proceed quantitatively and product **5c** was isolated in 72% yield after column chromatography, but started to decompose immediately after the isolation process. In order to determine the selectivity of the process (mono vs dihalogenation), SFRC halogenations were investigated on solid 3-oxo-3,*N*-diphenylpropionamide (**6**). No catalyst was needed to achieve selective monohalogenation at room temperature, despite the fact that the reaction mixtures remained solid, while yields of isolated products are slightly lower than in the case of diketone **4** with NCS and NBS, and higher for iodinated product **7c** (Table 2). The use of SFRC for halogenation of ketones and diketones with *N*-halosuccinimides was shown to be more selective than several published examples in which dihalogenation was usually enhanced by in-situ generation of acid or by a higher degree of enolization of monohalosubstituted substrates in solvents.[14] It is interesting to mention the effect of reaction temperature on the course of halogenation under SFRC (liquified reaction mixture), since at higher temperature (60 °C) selectivity was lost and further halogenation took place.

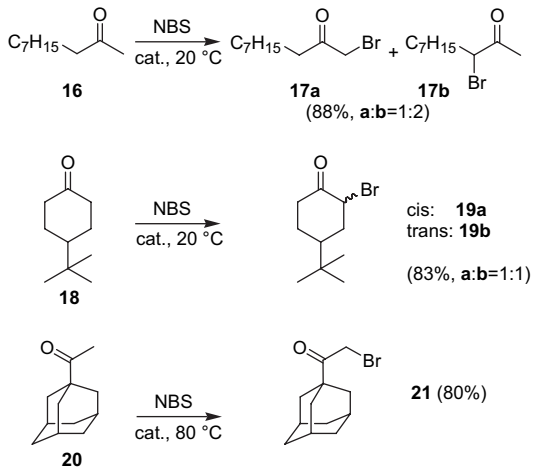
The effect of the trifluoromethyl group and various heteroaromatic groups on the regioselectivity of halogenation of 1,3-diketones was investigated under SFRC (Table 3). Similar to bromination with NBS,[9f] chlorination and iodination also proceed selectively and only monohalogenation of the methylene group was observed at room temperature in the absence of catalysts. It is

Table 3
SFRC halogenation of trifluoromethyl substituted 1,3-diketones with *N*-halosuccinimides and water-based work-up

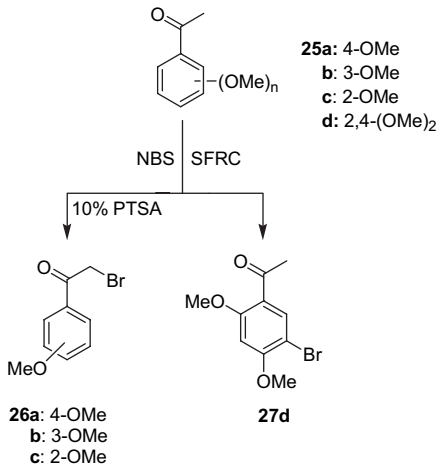


Subs.	R	Reagent[a]	Reaction time [h]	Prod.	Yield [%]
8		NCS	0.2	**11a**	71
		NBS	0.2	**12a**	91
		NIS	2	**13a**	86
9		NCS	1	**11b**	74
		NBS	0.2	**12b**	86
		NIS	1	**13b**	87
10		NCS	0.2	**11c**	80
		NBS	0.2	**12c**	90
		NIS	0.2	**13c**	79

[a] Reaction conditions: 1 mmol of substrate, 1 mmol of NXS.



Scheme 2.



Scheme 4.

interesting that introduction of halogen atoms enhances water addition to the carbonyl group next to the trifluoromethyl group in comparison to the starting material, and stable hydrates (1-substituted 2-halo-4,4,4-trifluoro-3,3-dihydroxybutan-1-ones, **11**–**13**) were isolated in high yields after a water-based work-up.

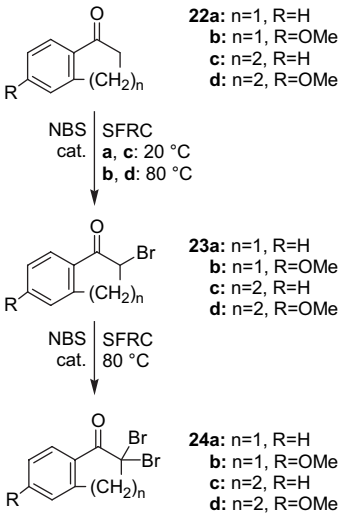
Further, we examined the effect of ketone structure on bromination with NBS under SFRC. Aliphatic 5-nonanone (**14**) did not react with NBS at room temperature, but 4-bromo-5-nonanone (**15**) was formed in 93% yield when 10% of PTSA was present.

Acid-catalyzed SFRC bromination of 2-decanone (**16**) was not regioselective, but a slight preference for substitution at the secondary carbon atom was observed and 1-bromo **17a** and 3-bromo **17b** were formed in 1:2 ratio (Scheme 2). No cis/trans preference for substitution in solid 4-*tert*-butyl-cyclohexanone (**18**) was observed, and *cis*-**19a** and *trans*-**19b** were formed in 1:1 ratio. Finally, on changing the phenyl group to a more bulky adamantyl (**20**, solid), bromination did not occur in the solid reaction mixture at room temperature, though high conversion was achieved above the melting point, at 80 °C after 10 min.

The influence of electron distribution between the oxygen atoms in aromatic ketones with the methoxy group in the *para* position to the carbonyl has already been demonstrated, the system being very sensitive to reaction conditions, which finally resulted in regioselective functionalization (ring vs side chain substitution).[1,11,12] We studied the effect of aggregate state, ring size and the presence of a methoxy group in benzocycloalcanones on the regioselectivity of acid-catalyzed bromination under SFRC (Scheme 3). At room temperature, both cyclopentanone **22a** and cyclohexanone **22c** derivatives were effectively functionalized at the side chain giving **23a** and **23c** in high yield, while introduction of a methoxy group in the *para* position (**22b**,**d**) did not change the regioselectivity, but both reaction mixtures had to be heated above their melting point (80 °C) for successful functionalization. Being interested in the regioselectivity of further bromination, we found that more rigorous conditions were necessary and substitution took place only at the α position, forming dibrominated **24a**–**d** in good yields after 1 h at 80 °C.

Since the methoxy group did not direct bromination to the ring position, we were stimulated to investigate its effect in three isomers of methoxy acetophenone (**25a**–**c**), which were all effectively brominated on the side chain after 2 h at room temperature in the presence of 10% PTSA (Scheme 4). Introduction of a second methoxy group changed the regioselectivity and 2,4-dimethoxy acetophenone (**25d**) was regioselectively transformed to 5-bromo derivative **27d** without the presence of PTSA after 24 h (88% conversion), while the presence of PTSA did not change the regioselectivity, but increased the reactivity (93% conversion after 2 h).

Further, we have examined the role of the aggregate state of acetophenones and the amount of acid catalyst (PTSA) on the course of bromination under SFRC. As evident from Figure 1, liquid



Scheme 3.

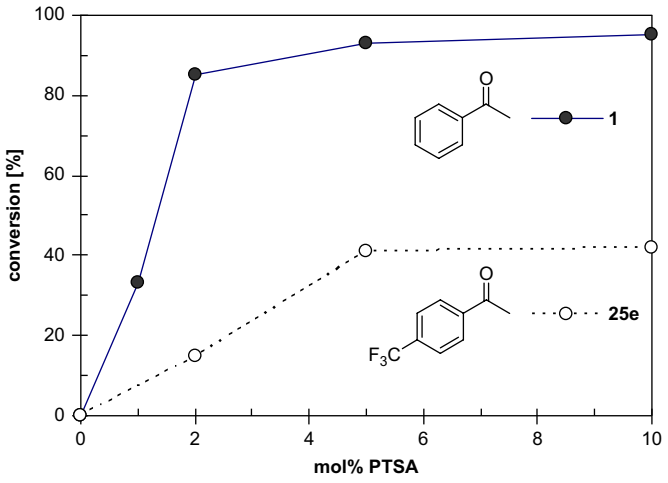


Figure 1. The effect of catalyst (PTSA) on the bromination of substituted acetophenones with NBS under SFRC at 20 °C (rt: **1**, 3 h; **25e**, 6 h).

acetophenone (**1**) responded differently from the solid substrate bearing an electron withdrawing group **25e** (*p*-CF_3), which was also shown to be less reactive and required more catalyst. Based on these results, 10% of PTSA was used for further halogenation to achieve stable reaction condition and the best reproducibility.

Migration of molecules in a reaction mixture is a very important process in SFRC transformations and attention must be paid to it when a transformation is declared to be a solid state one.[4b,15] It is known that molecules are much more mobile in liquid reaction mixtures, and this can be the case either with (1) liquid substrates, (2) solid substrates forming liquid reaction mixtures due to formation of a eutectic, or (3) due to formation of a liquid product (or eutectic). We studied the effect of reaction temperature on the bromination of solid 1,2-diphenylethanone (**28**). The reaction system composed of three solid compounds remained solid when triturated at room temperature and no reaction took place even after 24 h, but fast bromination was observed at 80 °C when the reaction system becomes molten. Figure 2 demonstrates the effect of reaction temperature on the course of bromination (conversions after 8 min) and it is evident that effective functionalization took place in the molten state.

In order to obtain some further insight into the bromination process, we investigated the effect of the aggregate state of two structurally similar ketones: solid indanone (**22a**) and liquid tetralone (**22c**). As evident from Table 4, the liquid substrate was almost twice as reactive as the solid one (entries 1 and 9). Further, we compared the reactivity of both substrates in two different solvents (methanol and acetonitrile) and it is interesting that solid **22a** was less reactive in methanol than under SFRC (entry 2). Tetralone reactivity was not affected (entry 10), but a further strong decrease of reactivity was noted in acetonitrile (entry 12). Preorganization (PO) of donor and acceptor molecules achieved in solution could have an important influence on further reactivity in transformations under SFRC.[16] Being interested in this effect, we decided to preorganize solid **22a** and liquid **22c** in two different solvents (methanol or acetonitrile). PO was achieved by dissolving the ketone, NBS and PTSA in the organic solvent, which was then evaporated under reduced pressure at 20 °C in 5 min and the reaction mixture was then left for additional 25 min at 20 °C. To obtain reproducible data, it is very important that after the reaction time NBS was immediately quenched with $NaHSO_3$.

Both ketones were more reactive in the preorganized state, but the increase in reactivity was much more pronounced for solid **22a** (entries 3 and 7). Conversions after 30 min did not reflect the influence of the solvent used for PO, in all cases being very high

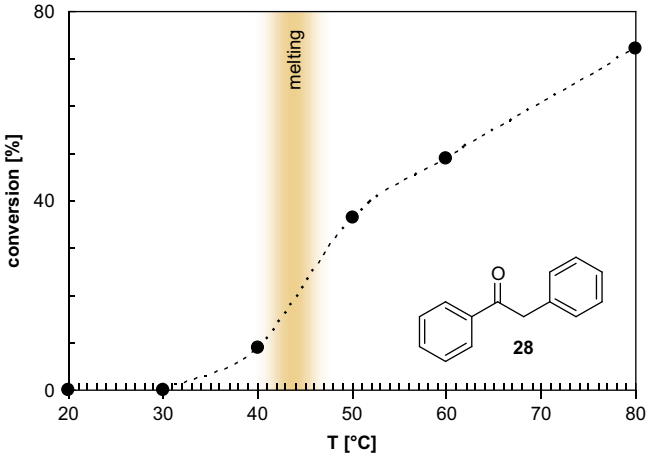


Figure 2. The effect of reaction temperature on the bromination of 1,2-diphenylethanone (**28**, solid) with NBS under SFRC (cat.: 10% PTSA; rt: 8 min).

Table 4
The effect of ketone structure, aggregate state (solid α-indanone: **22a**, liquid α-tetralone: **22c**, solid 1,2-diphenylethanone: **28**) and reaction conditions on bromination with NBS[a]

Entry	Comp.	Conditions	Conv. [%]
1	**22a**	SFRC[b]	44
2		SOL–MeOH[c]	17
3		PO–MeOH–SFRC[e]	88
4		PO–MeOH–SFRC[f]	73
5		AD–MeOH[d]	1
6		SOL–MeCN	8
7		PO–MeCN–SFRC	86
8		PO–MeCN–SFRC[f]	19
9	**22c**	SFRC	72
10		SOL–MeOH	70
11		PO–MeOH–SFRC	88
12		SOL–MeCN	5
13		PO–MeCN–SFRC	91
14		PO–MeCN–SFRC[f]	20
15	**28**	SFRC	69
16		SOL–MeCN	1
17		PO–MeCN–SFRC	72
18		PO–MeCN–SFRC[f]	14

[a] Ketone (0.5 mmol), NBS (0.5 mmol), PTSA (0.05 mmol), rt: 30 min, *T*: 20 °C for **22a** and **22c**, 40 °C for **28**.
[b] SFRC: solvent-free reaction conditions.
[c] SOL: reactants dissolved in 2.5 mL of named solvent; quenched after 30 min.
[d] AD: added 1.5 mmol of MeOH to reaction mixture and quenched after 5 min.
[e] PO: preorganization of reactants in 2.5 mL of named solvent, solvent evaporated (5 min), quenched after 25 min.
[f] Evaporated in 5 min and quenched.

(entries 3, 7, 11, and 13). A superior effect was observed when the reaction time was shortened to 5 min (including evaporation) and transformation after PO in methanol was much more effective than in acetonitrile (entries 4 and 8). It is interesting that almost the same degrees of conversion were observed after 5 min for both ketones when preorganized in acetonitrile (entries 8 and 14). To clarify the high effect of PO in methanol on the transformation, an additional experiment using a small amount of solvent (AD) was performed, but only negligible conversion was observed after 5 min (entry 5). It is interesting to compare this result with recently reported observations, that a small amount of added solvent significantly enhanced the transformation.[17] Finally, we evaluated the behaviour of solid diphenylethanone **28**, which was unreactive at room temperature, but bromination was achieved at 40 °C (entry 15); this ketone was also unreactive in acetonitrile (entry 16). The absence of a PO effect in acetonitrile was established (entry 17), indicating the important role of the substrate structure on PO and its potential further effect on SFRC transformations.

Many transformations of organic substrates could be effectively performed under SFRC, but only a very limited number of quantitative investigations were published.[3,4b] Furthermore, to our knowledge no kinetic investigations of brominations with NBS under SFRC have yet been published. We first investigated the kinetics of bromination of substituted acetophenones (liquid **1**, solid **25a** and **25e**) with NBS in the presence of 10% PTSA under SFRC. The study was performed at 40 °C—above the melting point of all substrates, and the progress of ketone consumption was monitored by ^{1}H NMR spectroscopy. Surprisingly a very good correlation (R^2>0.99) and reproducibility was found as evident from Figure 3, in which the reactions followed simple first order kinetics $v=k_{Br}$[ketone].

The *p*-methoxy derivative **25a** proved to be more (k_{Br}(**25a**)$^{40\,°C}$=1.8×10^{-3} s^{-1}), and *p*-trifluoromethyl **25e** less reactive (k_{Br}(**25e**)$^{40\,°C}$=0.6×10^{-3} s^{-1}) than acetophenone (k_{Br}(**1**)$^{40\,°C}$= 1.6×10^{-3} s^{-1}. Further, we verified whether the competitive reaction technique is applicable for SFRC transformations and the progress of

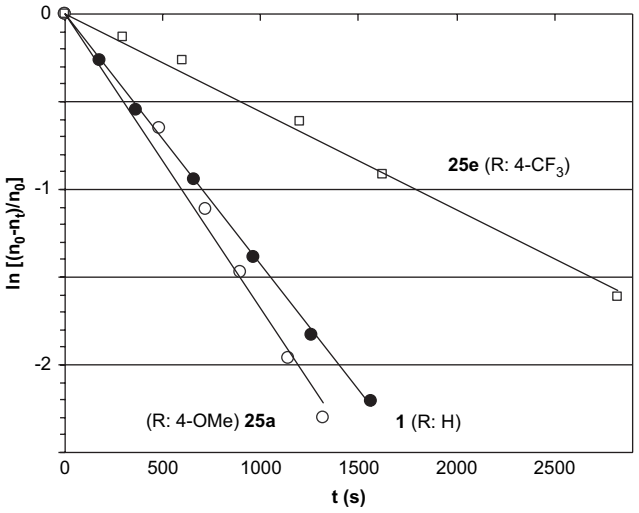
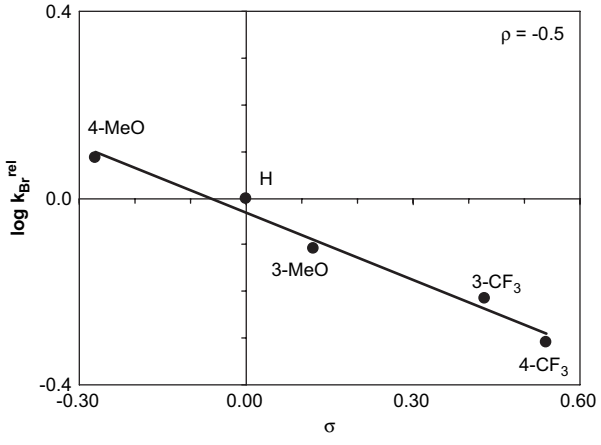


Figure 3. The course of SFRC bromination of substituted acetophenones (**1**: ●, **25a**: ○, **25e**: □) with NBS at 40 °C (10% PTSA).

bromination of an equimolar mixture of acetophenone, 4-trifluoromethyl acetophenone and NBS with 10% PTSA was analyzed after complete consumption of NBS. The resulting k_{Br}^{rel}=0.5 is in good agreement with relative rates calculated from first the order rate constants (k_{Br}(**1**)/k_{Br}(**25e**)=0.4), and therefore we used this competitive technique in further studies.

The Hammett correlation has already been used for discrimination of the two processes involved in bromination of acetophenones.[10] As evident from Figure 4, a negative correlation constant ρ=−0.5 was found for acid-catalyzed bromination with NBS under SFRC, indicating a moderate positive charge developed in the rate determining step.

It is interesting to compare SFRC with reaction in organic solvents. A significant increase in reaction rate was shown in the case



Subst. acetophenone		σ	pK_E	k_{Br}^{rel}
4-OMe	**25a**	-0.27	8.87	1.2
H	**1**	0.00	8.15	1.0
3-OMe	**25b**	0.12	8.15	0.8
3-CF_3	**25f**	0.43	7.78	0.6
4-CF_3	**25e**	0.54	7.57	0.5

Figure 4. Hammett correlation plot ($\log k_{Br}^{rel}/\sigma$) for the bromination of substituted acetophenones with NBS and 10% PTSA under SFRC at 20 °C.

Table 5
Effect of reaction conditions on the reactivity of methoxy substituted acetophenones with NBS[a]

Subst.	Acetophenone	k_{Br}^{rel}	
		MeCN, 60 °C	SFRC, 20 °C
H	**1**	1	1
2-OMe	**25c**	3	1.5
3-OMe	**25b**	1	0.8
4-OMe	**25a**	2.5	1.2

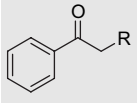
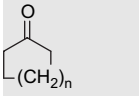
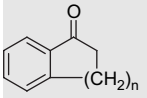
[a] Reaction in the presence of 10% PTSA, substr. conc: 0.2 M in MeCN.

of bromination of **22b** with NBS (Table 4; MeCN: 5% conversion, SFRC: 72% conversion after 30 min), therefore we examined the role of the solvent on the progress of side chain bromination of three isomeric methoxy substituted acetophenones (**25a–c**), comparing the reactions under SFRC. As evident from Table 5, the pattern of reactivity in acetonitrile is the same as under SFRC, but the effect of the substituent is more pronounced when the methoxy group is conjugated (*ortho* or *para* position) to the carbonyl group. In acetonitrile, the 2-methoxy (**25c**) isomer is 3 times, and 4-methoxy (**25a**) 2.5 times more reactive than acetophenone, while electron delocalization is less pronounced under SFRC (k_{Br}^{rel} 1.5 and 1.2, respectively). Introduction of a methoxy group at the *meta* position (**25b**) does not influence the reactivity of the ketone in acetonitrile, and only a small decrease was observed under SFRC.

Finally, we have studied the effect of ring size and the phenyl ring on the course of acid-catalyzed bromination of various cyclic ketones with NBS under SFRC (Table 6), in which all of them were converted to α-bromo derivatives. Cyclopentanone (**30a**) and cycloheptanone (**30c**) are only slightly more reactive than acetophenone (k_{rel}=1.2 and 1.5) while cyclohexanone is 10 times more reactive. Introduction of a phenyl ring enhances the reactivity of the five membered ring and indanone (**22a**) is 2.3 times more reactive than cyclopentanone, while tetralone (**22c**) is 4 times less reactive than cyclohexanone. The effect of introduction of a phenyl group into acetophenone was also examined and 1,2-diphenylethanone (**28**) was determined to be 3.3 times less reactive.

In order to understand the structural effects of ketones on bromination under SFRC, we tried to correlate reaction constants with pK_a values[18] and keto–enol equilibrium constants (pK_E).[19] No relationship was found with pK_a, but a good one with pK_E, although the dual behaviour of ketones is evident from Figure 5. In the substituted acetophenone series (**1**, **25a**,**b**,**e**,**f**), less enolized substrates are more reactive: $\log k_{Br}=0.3pK_E+C_1$. Functionalization obeys first order kinetics $v=k_{Br}$[ketone] and is probably controlled by the rate of enole formation (k_T^E), while further bromine addition is much faster than enolization. This could also be supported by the moderate positive charge, developed in the rate determining step,

Table 6
Effect of ketone structure on rate of bromination with NBS under SFRC at 20 °C (10% PTSA)

Substrate			pK_E	k_{Br}^{rel}
	R=H	**1**	8.15	1.0
	R=Ph	**28**		0.3
	*n*=1	**30a**	8.00	1.2
	n=2	**30b**	6.64	10
	n=3	**30c**	8.10	1.5
	*n*=1	**22a**	7.48	2.8
	n=2	**22c**		2.5

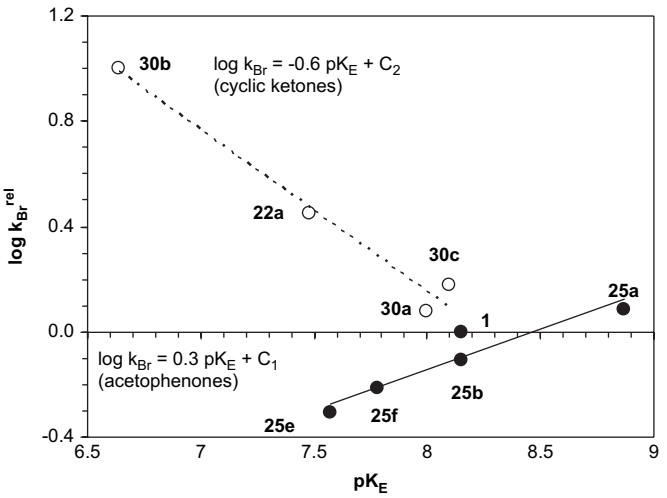
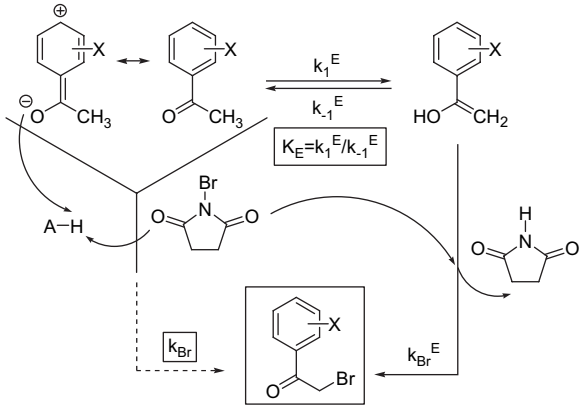


Figure 5. Correlation between the enolization (pK_E) of substituted acetophenones (●) and cyclic ketones (○) and the rate of NBS bromination under SFRC (10% PTSA; data from Table 4 and Fig. 4).

found in the Hammett correlation (ρ=−0.5). The important role of PTSA in activation of NBS and acetophenones must be taken into account in functionalization under SFRC (Scheme 5). On the other hand for cyclic ketones (**22a**, **30a–c**), an opposite association was observed: $\log k_{Br}$=−0.6pK_E+C_2, indicating the higher reactivity of substrates with a higher enolization constant (K_E).

3. Conclusion

A number of ketones were halogenated with *N*-halosuccinimides and PTSA as acid catalyst under solvent-free reaction conditions at various temperatures in molten reaction mixtures (20–80 °C), while halogenation of more enolized 1,3-diketones and β-ketoamide also proceeded in the solid state and without catalyst. The process was shown to be very selective and quicker than if performed in organic solvents (acetonitrile, methanol). Aryl substituted ketones are brominated on the side chain, even in the case of introduction of a second bromine atom into a methoxy substituted derivative and the bromination of substituted acetophenones obeys first order kinetics v=k_{Br}[ketone]. For cyclic ketones (**22a**, **30a–c**), the correlation $\log k_{Br}$=−0.6pK_E+C_2 was determined, while acetophenones (**1**, **25a**,**b**,**e**,**f**) show an opposite correlation ($\log k_{Br}$=0.3pK_E+C_1). The negative Hammett correlation with ρ=−0.5 indicates a moderate positive charge, developed in the rate determining step.



Scheme 5.

4. Experimental

4.1. General

Melting points were determined on a Büchi 535 apparatus. ^{1}H and ^{13}C NMR spectra were recorded on a Varian INOVA 300 spectrometer at 300 MHz and 76 MHz, respectively. Chemical shifts are reported in parts per million from TMS as the internal standard, using $CDCl_3$ as a solvent. ^{19}F NMR spectra were recorded on the same instrument at 285 MHz and chemical shifts are reported in parts per million from CCl_3F as the internal standard. IR spectra were obtained with a Bio-Rad FTS 3000MX. Standard KBr pellet procedures were used to obtain IR spectra of solids, while a film of neat material was used to obtain IR spectra of liquid products. Mass spectra were obtained on an Autospec Q instrument under electron impact (EI) conditions at 70 eV. Elemental analyses were carried out on a Perkin Elmer 2400 Series II CHNS/O Analyzer. *N*-halosuccinimides (Merck) and starting substrates (Sigma–Aldrich, Fluka) were used as received, while *p*-toluenesulfonic acid (PTSA) was dried at 120 °C for 2 h and stored in a dry atmosphere. ACS grade solvents were used.

Isolated compounds were identified on the basis of spectroscopic data, elemental microanalysis and high resolution MS spectrometry, while in the case of known compounds comparison with literature data was made. In cases where spectroscopic data is not stated, it is in accordance with previously reported data. All conversions were determined using ^{1}H or ^{19}F NMR spectroscopy. Crystallization or column chromatography were used for purification of products where stated.

4.2. Halogenation of ketones (1, 14, 16, 18, 20, 22a–d, 25a–f, 28, 30a–c) under SFRC: general procedure

Substrate (1 mmol) and *N*-halosuccinimide (NXS, 1 mmol) were triturated together with *p*-toluenesulfonic acid (PTSA, 0.1 mmol) in a porcelain mortar for 2–10 min. Most reaction mixtures melted during reaction at 20 °C, while mixtures with **20**, **22b**, **22d** and **28** were heated to 80 °C for 10 min to achieve melting. After the reaction time (see Table 1 and compounds description), water (5 mL) was added, followed by extraction with *tert*-butyl methyl ether or CH_2Cl_2 (10 mL). The organic phase was washed with water (10 mL), dried over Na_2SO_4 and solvent evaporated under reduced pressure.

*4.2.1. 2-Chloro-1-phenylethanone[20,21] (**2a**)*

Reaction performed with 2 mmol of ketone **1**; crude product (84% **2a**, 6% **3a**) was purified by column chromatography (SiO_2: CH_2Cl_2/hexane=10:1, 70%), mp 54–55 °C (lit.[21] 54–55 °C).

*4.2.2. 2,2-Dichloro-1-phenylethanone[22] (**3a**)*

Isolated as a minor component in synthesis of **2a** from crude product (84% **2a**, 6% **3a**), purified by column chromatography (SiO_2: CH_2Cl_2/hexane=10:1), oily product (4%).

*4.2.3. 2-Bromo-1-phenylethanone[23,24] (**2b**)*

Crude product (95%) was crystallized, mp 47–48 °C (from ethanol; lit.[24] 46–48 °C).

*4.2.4. 2-Iodo-1-phenylethanone[25] (**2c**)*

Crude product (81%) additionally purified by column chromatography (SiO_2: CH_2Cl_2/hexane=10:1), oily product.

*4.2.5. 4-Bromononan-5-one[26] (**15**)*

Reaction time: 2 h; oily product (93%).

4.2.6. 1-Bromodecan-2-one[27] (***17a***) *and 3-bromo-decan-2-one*[28] (***17b***)

Reaction time: 4 h; crude reaction mixture (88%) composed of **17a** and **17b** in 1:2 ratio.

4.2.7. 2-Bromo-4-tert-butyl-cyclohexanone[29;30] *(cis:* ***19a****, trans:* ***19b****)*

Reaction time: 2 h; crude reaction mixture contained 83% of both isomers in 1:1 ratio. **19a** crystallized from pentane, mp 63–65 °C (lit.[30] 66 °C).

4.2.8. 1-Adamantan-1-yl-2-bromoethanone[31] (***21***)

Crude product (80%) was crystallized, mp 79–80 °C (from ethanol; lit.[31] 78–79 °C); ^{1}H NMR (300 MHz; $CDCl_3$) δ 1.67–1.79 (m, 6H, CH_2), 1.88 (d, J=2.7 Hz, 6H, CH_2), 2.01–2.1 (s, 3H, CH), 4.16 (s, 2H, CH_2Br); ^{13}C NMR (76 MHz; $CDCl_3$) δ 27.8, 31.8, 36.3, 38.5, 46.6, 205.5 (CO).

4.2.9. 2-Bromoindan-1-one[32] (***23a***)

Reaction time: 2 h; purified by column chromatography (SiO_2: CH_2Cl_2, 87%), mp 36–37 °C (lit.[32] 37–38 °C).

4.2.10. 2-Bromo-5-methoxyindan-1-one[33] (***23b***)

Crude product (97%) was crystallized, mp 105–107 °C (from ethanol; lit.[33] 107.8–108.5 °C); ^{1}H NMR (300 MHz; $CDCl_3$) δ 3.37 (dd, J=18.2 Hz, 3.1 Hz, 1H), 3.79 (dd, J=18.2 Hz, 7.5 Hz, 1H), 3.91 (s, 3H, CH_3O), 4.64 (dd, J=3.1 Hz, 7.5 Hz, 1H, CHBr), 6.86 (d, J=2.1 Hz, 1H, ArH), 6.96 (dd, J=2.1 Hz, 8.6 Hz, 1H, ArH), 7.77 (d, J=8.6 Hz, 1H, ArH); ^{13}C NMR (76 MHz; $CDCl_3$) δ 38.0, 44.6, 55.8, 106.3 (ArC), 109.4 (ArCH), 116.3 (ArCH), 126.8 (ArCH), 154.1 (ArC), 166.3 (ArC), 197.6 (CO).

4.2.11. 2-Bromo-1-tetralone[32,34] (***23c***)

Reaction time: 2 h; purified by column chromatography (SiO_2: CH_2Cl_2, 86%), mp 36–37 °C (lit.[32] 38–39 °C).

4.2.12. 2-Bromo-6-methoxy-1-tetralone[35] (***23d***)

Crude product (97%) was crystallized, mp 78–79 °C (from ethanol; lit.[35] 79–81 °C).

4.2.13. 2-Bromo-1-(4-methoxyphenyl)-ethanone[36,37] (***26a***)

Reaction time: 2 h; crude product (73%) was crystallized, mp 68 °C (from ethanol; lit.[37] 69–70 °C).

4.2.14. 2-Bromo-1-(3-methoxyphenyl)-ethanone[38] (***26b***)

Reaction time: 2 h; crude product (85%) was crystallized, mp 61–62 °C (from ethanol; lit.[38] 55–57 °C); ^{1}H NMR (300 MHz; $CDCl_3$) δ 3.86 (s, 3H, CH_3O), 4.45 (s, 2H, CH_2Br), 7.14 (ddd, J=1.0, 2.5, 8.2 Hz, 1H), 7.39 (dd, J=7.6, 8.2 Hz, 1H), 7.50 (dd, J=1.5, 2.5 Hz, 1H), 7.54 (ddd, J=7.6, 1.5, 1.0 Hz, 1H); ^{13}C NMR (76 MHz; $CDCl_3$) δ 30.9 (CH_3), 55.5 (CH_2Br), 113.1 (ArCH), 120.5 (ArCH), 121.4 (ArCH), 129.8 (ArCH), 135.3 (ArC), 160.0 (ArC), 191.1 (CO).

4.2.15. 2-Bromo-1-(2-methoxyphenyl)-ethanone[39,40] (***26c***)

Reaction time: 2 h; crude product (91%) was crystallized, mp 42–43 °C (from ethanol; lit.[40] 40–44 °C).

4.2.16. 1-(5-Bromo-2,4-dimethoxyphenyl)-ethanone[41] (***27d***)

Reaction time: 2 h; crude product (93%) was crystallized (67%), mp 138–139 °C (from ethanol; lit.[41] 139–140 °C); ^{1}H NMR (300 MHz; $CDCl_3$) δ 2.56 (s, 3H, CH_3), 3.94 (s, 3H, CH_3O), 3.96 (s, 3H, CH_3O), 6.45 (s, 1H, ArH), 8.03 (s, 1H, ArH); ^{13}C NMR (76 MHz; $CDCl_3$) δ 31.8 (CH_3), 55.8 (CH_3O), 56.4 (CH_3O), 95.8 (ArCH), 102.7 (ArC), 121.4 (ArC), 135.1 (ArCH), 160.0 (ArC), 160.4 (ArC), 196.3 (CO); MS m/z (EI, 70 eV) 260 (45%, M^+), 258, 245, 243 (100%); high resolution MS m/z 257.9902 (calcd for $C_{10}H_{11}BrO_3$: 257.9892).

4.2.17. 2-Bromo-1-(4-trifluoromethylphenyl)-ethanone[42] (***26e***)

Reaction time: 18 h; crude product (96%) was crystallized (54%), mp 54–55 °C (from ethanol; lit.[42] 53–54 °C); ^{19}F NMR (285 MHz; $CDCl_3$) δ −63.8.

4.2.18. 2-Bromo-1-(3-trifluoromethylphenyl)-ethanone[43] (***26f***)

Reaction time: 18 h; crude product (89%) purified by column chromatography (SiO_2: CH_2Cl_2/hexane=10:1), oily product (66%); ^{1}H NMR (300 MHz; $CDCl_3$) δ 4.47 (s, 2H), 7.66 (dd, J=7.8 Hz, 7.8 Hz, 1H), 7.87 (d, J=7.8 Hz, 1H), 8.18 (d, J=7.8 Hz, 1H), 8.24 (s, 1H); ^{19}F NMR (285 MHz; $CDCl_3$) δ −63.3.

4.2.19. 2-Bromo-1,2-diphenylethanone[44] (***29***)

Crude product (95%) was crystallized, mp 53–55 °C (from ethanol; lit.[44] 55–56 °C).

4.2.20. 2-Bromo-cyclopentanone[45] (***31a***)

Reaction time: 2 h; crude product (86%) purified by column chromatography (SiO_2: CH_2Cl_2), oily product (84%); ^{1}H NMR (300 MHz; $CDCl_3$) δ 1.97–2.08 (m, 1H), 2.15–2.30 (m, 3H), 2.35–2.45 (m, 2H), 4.22–4.26 (m, 1H, CHBr). Decomposition observed after a few days at 6 °C.

4.2.21. 2-Bromo-cyclohexanone[23] (***31b***)

Reaction time: 2 h; crude product (96%) purified by column chromatography (SiO_2: CH_2Cl_2), oily product (93%).

4.2.22. 2-Bromo-cycloheptanone[46] (***31c***)

Reaction time: 2 h; crude product (93%) purified by column chromatography (SiO_2: CH_2Cl_2), oily product (84%).

4.3. Halogenation of 1,3-dicarbonyl compounds (4, 6, 8–10) under SFRC: general procedure

Substrate (1 mmol) and NXS (1 mmol) were triturated together in a porcelain mortar for 5 min and left for 10–180 min at 20 °C (reaction times noted in Table 2 and Table 3). Water (4 mL) was then added and the mixture triturated for 1 min. In the case of halogenation of **4** (giving **5a**–**c**) and chlorination of **9** (giving **11b**), this was followed by extraction with *tert*-butyl methyl ether or CH_2Cl_2 (20 mL), washing the organic phase with water (10 mL), drying over Na_2SO_4 and evaporation of solvent under reduced pressure, while in other cases filtration of the solid product, washing with water (20 mL) and drying in a desiccator under reduced pressure was used.

4.3.1. 2-Acetyl-2-chlorocyclohexanone[47] (***5a***)

Oily product (95%).

4.3.2. 2-Acetyl-2-bromocyclohexanone[9f] (***5b***)

Oily product (98%); ^{1}H NMR (300 MHz; $CDCl_3$) δ 1.72–1.91 (m, 2H), 1.91–2.07 (m, 2H), 2.16–2.29 (m, 1H), 2.29–2.42 (m, 1H), 2.45 (s, 3H), 2.51–2.67 (m, 1H), 3.06–3.20 (m, 1H).

*4.3.3. 2-Acetyl-2-iodocyclohexanone (****5c****)*

Purified by column chromatography (SiO_2: CH_2Cl_2), oily product (72%); ^{1}H NMR (300 MHz; $CDCl_3$) δ 1.78–2.01 (m, 4H), 2.24–2.52 (m, 3H), 2.56 (s, 3H), 3.22–3.35 (m, 1H); ^{13}C NMR (76 MHz; $CDCl_3$) δ 23.9, 27.1, 27.4, 38.3, 40.4, 59.4, 200.7 (CO), 203.2 (CO); IR ν_{max}(KBr)/cm^{-1} 1694, 1431, 1366, 1224, 1177, 1115, 1065, 965; MS m/z (EI, 70 eV) 266 (2%), 224 (100%), 111 (25%), 97 (45%), 55 (30%); high resolution MS: m/z 265.9812 (calcd for $C_8H_{11}IO_2$: 265.9804). The product was not stable and started to decompose immediately after chromatography.

*4.3.4. 2-Chloro-3-oxo-3,N-diphenylpropionamide[48] (**7a**)*

Crude product was crystallized (67%), mp 118–119 °C (from ethanol; lit.[48] 116–118 °C); ^{1}H NMR (300 MHz; $CDCl_3$) δ 5.81 (s, 1H), 7.16 (t, J=7.4 Hz, 1H), 7.29–7.38 (m, 2H), 7.47–7.58 (m, 4H), 7.60–7.69 (m, 1H), 8.03–8.12 (m, 2H), 8.41 (s, 1H, NH).

*4.3.5. 2-Bromo-3-oxo-3,N-diphenylpropionamide[49] (**7b**)*

Crude product was crystallized (85%), mp 133–134 °C (from ethanol; lit.[49] 132–123.5 °C).

*4.3.6. 2-Iodo-3-oxo-3,N-diphenylpropionamide[50] (**7c**)*

Crude product was crystallized (83%), mp 131–134 °C (from ethanol; lit.[50] 138–140 °C); ^{1}H NMR (300 MHz; $CDCl_3$) δ 5.92 (s, 1H, CHI), 7.14 (t, J=7.4 Hz, 1H), 7.34 (t, J=7.9 Hz, 2H), 7.51 (t, J=7.6 Hz, 2H), 7.56–7.71 (m, 3H), 8.02 (d, J=7.3 Hz, 2H), 9.63 (s, 1H, NH).

*4.3.7. 2-Chloro-4,4,4-trifluoro-3,3-dihydroxy-1-phenylbutan-1-one (**11a**)*

Crude product was crystallized (71%), mp 74–75 °C (from $CHCl_3$); ^{1}H NMR (300 MHz; $CDCl_3$) δ 4.43 (s, 1H), 5.36 (s, 1H), 5.56 (s, 1H), 7.54–7.60 (m, 2H), 7.69–7.75 (m, 1H), 7.99–8.04 (m, 2H); ^{19}F NMR (285 MHz; $CDCl_3$) δ −83.0; IR ν_{max}(KBr)/cm^{-1} 3387 (OH), 1671, 1595, 1208, 1175, 1090, 1007, 970, 683, 630; MS m/z (EI, 70 eV), 269 (10%, MH$^+$), 154 (30%), 105 (100%), 77 (62%); high resolution MS m/z 269.0202 (MH$^+$; calcd for $C_{10}H_8ClF_3O_3$: 269.0192). Anal. Calcd for $C_{10}H_8ClF_3O_3$ C, 44.71; H, 3.00. Found: C, 44.49; H, 3.01.

*4.3.8. 2-Chloro-4,4,4-trifluoro-1-furan-2-yl-3,3-dihydroxybutan-1-one (**11b**)*

Crude product was crystallized (74%), mp 79–80 °C (from $CHCl_3$); ^{1}H NMR (300 MHz; $CDCl_3$) δ 4.37 (s, 1H, OH), 5.26 (s, 1H, CHCl), 5.37 (s, 1H, OH), 6.70 (dd, J=3.7, 1.7 Hz, 1H, ArH), 7.51 (dd, J=3.7, 0.7 Hz, 1H, ArH), 7.78 (dd, J=1.7, 0.7 Hz, 1H, ArH); ^{19}F NMR (285 MHz; $CDCl_3$) δ −83.1; IR ν_{max}(KBr)/cm^{-1} 3355 (OH), 1660, 1570, 1464, 1328, 1206, 1174, 1136, 1087, 986, 722, 658; MS m/z (EI, 70 eV) 258 (9%, M$^+$), 144 (20%), 95 (100%), 68 (15%); high resolution MS m/z 257.9914 (calcd for $C_8H_6ClF_3O_4$: 257.9907). Anal. Calcd for $C_8H_6ClF_3O_4$ C, 37.16; H, 2.34. Found: C, 37.51; H, 2.39.

*4.3.9. 2-Chloro-4,4,4-trifluoro-3,3-dihydroxy-1-thiophen-2-ylbutan-1-one (**11c**)*

Crude product was crystallized (80%), mp 97–98 °C (from $CHCl_3$); ^{1}H NMR (300 MHz; $CDCl_3$) δ 4.47 (s, 1H), 5.19 (s, 1H), 5.49 (s, 1H), 7.21–7.29 (m, 1H), 7.87–7.93 (m, 2H); ^{19}F NMR (285 MHz; $CDCl_3$) δ −82.9; IR ν_{max}(KBr)/cm^{-1} 3354 (OH), 1645, 1410, 1198, 1133, 1092, 864, 733; MS m/z (EI, 70 eV) 274 (2%, M$^+$), 111 (100%), 84 (15%), 69 (12%); high resolution MS m/z 273.9688 (calcd for $C_8H_6ClF_3O_3S$: 273.9678); Anal. Calcd for $C_8H_6ClF_3O_3S$ C, 34.99; H, 2.20. Found: C, 35.20; H, 2.27.

*4.3.10. 2-Iodo-4,4,4-trifluoro-3,3-dihydroxy-1-phenylbutan-1-one (**13a**)*

Crude product was crystallized (86%), mp 90–92 °C (from $CHCl_3$, decomposition); ^{1}H NMR (300 MHz; $CDCl_3$) δ 4.37 (s, 1H), 5.70 (s, 1H), 5.92 (s, 1H), 7.50–7.59 (m, 2H), 7.66–7.74 (m, 1H), 7.96–8.01 (m, 2H); ^{19}F NMR (285 MHz; $CDCl_3$) δ −82.2; IR ν_{max}(KBr)/cm^{-1} 3383 (OH), 1659, 1204, 1175, 1066, 968, 728, 683, 623; MS m/z (EI, 70 eV) 360 (2%, M$^+$), 147 (20%), 105 (100%), 77 (50%), 69 (27%); high resolution MS m/z 359.9483 (calcd for $C_{10}H_8F_3IO_3$: 359.9470). Anal. Calcd for $C_{10}H_8F_3IO_3$ C, 33.36; H, 2.24. Found: C, 33.17; H, 2.26.

*4.3.11. 2-Iodo-4,4,4-trifluoro-1-furan-2-yl-3,3-dihydroxybutan-1-one (**13b**)*

Crude product was crystallized (87%), mp 91–93 °C (from $CHCl_3$, decomposition); ^{1}H NMR (300 MHz; $CDCl_3$) δ 4.36 (s, 1H, OH), 5.62 (s, 1H), 5.73 (s, 1H, OH), 6.68 (dd, J=3.7, 1.7 Hz, 1H), 7.48 (dd, J=3.7, 0.7 Hz, 1H), 7.71–7.76 (m, 1H); ^{19}F NMR (285 MHz; $CDCl_3$) δ −82.4; IR ν_{max}(KBr)/cm^{-1} 3378 (OH), 1649, 1464, 1402, 1175, 1120, 1090, 1005, 977, 770, 716; MS m/z (EI, 70 eV) 350 (2%, M$^+$), 236 (25%), 95 (100%), 69 (25%); high resolution MS m/z 349.9270 (calcd for $C_8H_6F_3IO_4$: 349.9263). Anal. Calcd for $C_8H_6F_3IO_4$ C, 27.45; H, 1.73. Found: C, 27.29; H, 1.71.

*4.3.12. 2-Iodo-4,4,4-trifluoro-3,3-dihydroxy-1-thiophen-2-ylbutan-1-one (**13c**)*

Crude product was crystallized (79%), mp 100–101 °C (from $CHCl_3$, decomposition); ^{1}H NMR (300 MHz; $CDCl_3$) δ 4.36 (s, 1H, OH), 5.55 (s, 1H, CHI), 5.83 (s, 1H, OH), 7.19–7.28 (m, 1H, ArH), 7.80–7.91 (m, 2H, ArH); ^{19}F NMR (285 MHz; $CDCl_3$) δ −82.2; IR ν_{max}(KBr)/cm^{-1} 3337 (OH), 3217 (OH), 1632, 1409, 1204, 1172, 1067, 735; MS m/z (EI, 70 eV) 366 (4%, M$^+$), 153 (18%), 111 (100%), 69 (28%); high resolution MS m/z 365.9049 (calcd for $C_8H_6F_3IO_3S$: 365.9034). Anal. Calcd for $C_8H_6F_3IO_3S$ C, 26.25; H, 1.65. Found: C, 26.24; H, 1.70.

4.4. Dibromination of ketones (22a–d) under SFRC: general procedure

Ketone (1 mmol) and *N*-bromosuccinimide (NBS, 2 mmol) were triturated together with PTSA (0.1 mmol) in a porcelain mortar for 2 min. The reaction mixture was then heated to 80 °C for 1 h, turning it into a dense paste. Water was then added (5 mL) followed by extraction with *tert*-butyl methyl ether or CH_2Cl_2 (20 mL). The organic phase was washed with water (10 mL), dried over Na_2SO_4 and solvent evaporated under reduced pressure.

*4.4.1. 2,2-Dibromoindanone[51] (**24a**)*

Crude product (99%) was crystallized, mp 132–133 °C (from ethanol; lit.[51] 133–134 °C).

*4.4.2. 2,2-Dibromo-5-methoxyindan-1-one[1] (**24b**)*

Crude product (98%) was crystallized, mp 109–110 °C (from ethanol; lit.[1] 109–110 °C).

*4.4.3. 2,2-Dibromo-1-tetralone[32] (**24c**)*

Crude product (88%) was crystallized, mp 57–58 °C (from ethanol; lit.[32] 58–60 °C); ^{13}C NMR (76 MHz; $CDCl_3$) δ 29.3 (CH_2), 45.8 (CH_2), 67.1 (CBr_2), 127.3 (ArC), 127.5 (ArCH), 128.6 (ArCH), 130.0 (ArCH), 134.4 (ArCH), 142.0 (ArC), 184.1 (CO).

*4.4.4. 2,2-Dibromo-6-methoxy-1-tetralone[52] (**24d**)*

Crude product (70%) was crystallized, mp 78–80 °C (from ethanol; lit.[52] 85 °C).

4.5. The effect of preorganization of substrates (PO) and addition of solvent (AD) on the bromination of 22a, 22c and 28 with NBS

PO: NBS (0.5 mmol) and PTSA (0.05 mmol) were first dissolved in MeOH or MeCN (2.5 mL), and substrate (0.5 mmol) was then added. Evaporation of solvent under reduced pressure (bath temperature 20 °C) was then performed for 5 min. Reaction was quenched with $NaHSO_3$ either after the described evaporation of solvent, or 25 min later (see Table 4).

AD: Substrate (0.5 mmol), NBS (0.5 mmol), PTSA (0.05 mmol) and 5 drops of cold MeOH (1.5 mmol) were mixed in a porcelain mortar. A pasty mixture resulted and the mortar was then covered to prevent solvent evaporation. Reaction was quenched with $NaHSO_3$ after 5 min at room temperature and the usual isolation procedure was performed.

4.6. Determination of rate order constants for functionalization of 1-phenylethanone (1), 1-(4-methoxyphenyl) (25a) and 1-(4-trifluoromethyl)-ethanone (25e) with NBS under SFRC at 40 °C

To a thermostatted mixture of substrate (2 mmol) and PTSA, NBS (2 mmol) was added. The flask with reaction mixture was then rotated in a thermostatted bath using a Büchi R124 apparatus. During reaction, some of the reaction mixture was removed from the flask into a water solution of $NaHSO_3$ (quenching) and after micro-isolation with $CDCl_3$, conversion was determined using ^1H NMR. First order rate constants were calculated from Eq. 1: $\ln[(n_0-n_t)/n_0]=k_{Br}t$ and a linear relationship was found with $k_{Br}^{40\,°C}$ 1.6×10^{-3}, 1.8×10^{-3} and 0.6×10^{-3} s^{-1} for **1**, **25a** and **25b**, respectively, with R^2 being over 0.99. These results were determined to be reproducible while first rate order was also confirmed by experiments using a different substrate–NBS ratio.

Relative reactivities of ketones **1**, **22a–c**, **25a–c**,**e**,**f**, **30a–c** were determined by competitive reactions with NBS under SFRC at 20 °C as follows: Substrate (1 mmol) and acetophenone (1, 1 mmol) were triturated together with PTSA (0.1 mmol) in porcelain mortar for 2 min. NBS (1 mmol) was added to the liquid reaction mixture, which was then triturated for 2 min. After 24 h, water was added (10 mL), followed by usual extraction procedure. Product mixture was analyzed using ^1H NMR. Applying this known competitive technique, relative rate factors (k_{Br}^{rel}) were calculated from Eq. 2: $k_{Br}^{rel}=k_A/k_B=\log[A/(A+X)]/\log[B/(B+Y)]$, derived from the Ingold–Shaw[53] relation, where A and B are molar amounts of the starting material and X and Y are molar amounts of products derived from them (molar amounts of compounds in the reaction mixture after reaction time).

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