The present results are at variance with previous reports on the reactivity pattern of C_2H_5MgI with nitrobenzene.

Oddo[5] in 1904 reported formation of *N*-ethylaniline and two unidentified distillation fractions.

Conversely, formation of tetrasubstituted hydrazine as the main product was reported by Gilman and McCraken.[6]

No products of N-alkylation were isolated from our experiments.

Comparison of the present findings with our previous data[1] and the ones on reactions with aryl Grignard reagents[7,8] strongly suggest that prevalence of each type of addition will not be dependent upon the aromatic substrate[1c] carrying the nitro group, but it appears to be dependent upon the nature of the Grignard reagent; thus conjugate addition will prevail with alkyl reagents, while with aryl derivatives 1,2 addition takes place.

Finally the ortho and para orientation of the attack with respect to the nitro group confirms the nucleophilic character[1c] of the alkylation process.

Experimental Section

IR, UV, and ^{1}H NMR spectra were recorded with Perkin-Elmer 275, Perkin 402, and Jeol 60 MHz [$(Me)_4Si$ as internal standard] instruments, respectively.

THF and diethyl ether were purified by distilling under a nitrogen atmosphere after refluxing over sodium. They were stored over sodium wire and distilled from lithium aluminum hydride before using.

Reaction Procedure. A solution of alkylmagnesium halide (0.02 mol) in THF or Et_2O (50 mL) was added dropwise at −70 °C under nitrogen to a solution of *p*-nitrotoluene (0.01 mol) in the same solvent (50 mL). The cooling bath was removed immediately after addition was completed, and 5 mL of aqueous HCl (27%) was added. The reaction mixture was allowed to stir for 1 min and then diluted with cold water. After extraction of the aqueous mixture with CH_2Cl_2, the organic layer was washed several times with water, dried, and evaporated at low pressure. The residue was submitted to chromatographic separation on a silica gel column. Elution with cyclohexane–ethyl acetate (4:1) gave product **3; 3a** (R = CH_3) was obtained free of impurities. It was crystallized from *n*-hexane: mp 39–41 °C dec (lit.[9] 38–41.5 °C) (yield 48–53%);[10] UV ($CHCl_3$) λ_{max} (ϵ) 765 nm (32); IR (CCl_4) 1450 cm^{-1} (N=O); ^{1}H NMR ($CDCl_3$) δ 2.50 and 3.45 (s, 3 H and 3 H, CH_3 and CH_3), 6.30 (d, $J_{5,6}$ = 8.5 Hz, 1 H, H-6), 7.05 (dd, $J_{3,5}$ ~ 2 Hz, 1 H, H-5), 7.45 (d, 1 H, H-3).

3b (R = *n*-C_4H_9) was obtained mixed with 5% of a product which has been tentatively identified from the ^{1}H NMR spectrum of the mixture as the corresponding nitro derivative. It was purified by chromatography on silica gel using *n*-hexane as eluent.

3b: green oil (yield 45–50%);[10] IR 1450 cm^{-1} (N=O); UV ($CHCl_3$); λ_{max} (ϵ) 765 nm (32); ^{1}H NMR (CCl_4) δ 0.8–2.20 and 3.75–4.15 (m, 7 H, 2 H, *n*-C_4H_9), 2.45 (s, 3 H, $-CH_3$), 6.15 (d, $J_{5,6}$ = 8.5 Hz, 1 H, H-6), 7.00 (dd, $J_{3,5}$ ~ 2 Hz, 1 H, H-5), 7.45 (d, 1 H, H-3).

Anal. Calcd for $C_{11}H_{15}NO$: C, 74.54; H, 8.53; N, 7.90. Found: C, 74.65; H, 8.21; N, 8.01.

Further elution of the column with cyclohexane–ethyl acetate (1:1) gave **5** free from impurities.

5a (R = CH_3, yield 11–15%)[10] showed physical and spectroscopic characteristics identical with those reported in literature.[4,11]

5b (R = *n*-C_4H_9, yield 22–25%):[10] pale yellow oil; IR (in film) 1660 (C=O), 1620 (C=C) cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.8–1.9 (m, 9 H, *n*-C_4H_9), 1.25 (s, 3 H, $-CH_3$), 6.15–6.75 (AB system, J = 10 Hz, 2 H and 2 H, H-2, H-6 and H-3, H-4).

Anal. Calcd for $C_{11}H_{16}O$: C, 80.44; H, 9.83. Found: C, 80.05; H, 9.77.

Acknowledgment. This work was carried out with the financial aid of the C.N.R. Rome.

Registry No.—**1**, 99-99-0; **3a**, 38974-06-0; **3b**, 66270-57-3; **5a**, 1073-14-9; **5b**, 66270-58-4.

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A New and Convenient Synthesis of 1-Aryl-1,2-alkanediones

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The conversion of a methylene group α to a ketone into a carbonyl group to afford a 1,2-dione is an important functional group transformation in organic synthesis.

Numerous syntheses of the title compounds have been reported already, among others oxidation of aryl alkyl ketones,[1,2] alkenes,[3] alkynes,[4] and acylmethylenephenylphosphoranes.[5] By far the most used procedure for the synthesis of α-diketones **5** involved the base-induced α elimination of α-nitrato ketones.[6,7,8] More generally applicable methods for the synthesis of α-diketones involved the use of less general reagents such as *tert*-butoxybis(dimethylamino)methane[10] and pentacarbonyliron.[11] Finally, acetoxylation of β-keto sulfides leads also to 1,2-dicarbonyl compounds.[12]

We wish to report a convenient and mild method for the synthesis of 1-aryl-1,2-alkanediones **5**. Our method can be used in molar quantities and proceeds according to the reaction sequence outlined in Scheme I.

Recently,[13] we described a high-yield synthesis of 1-aryl-2,2-dichloro-1-alkanones **2** involving conversion of alkyl aryl ketones **1** into the corresponding *N*-cyclohexylketimines, which were chlorinated in the α position of the imino function by means of *N*-chlorosuccinimide in carbon tetrachloride at room temperature, the resulting *N*-1-(1-aryl-2,2-dichloroalkylidene)cyclohexylamines being hydrolyzed with aqueous hydrogen chloride solution to the corresponding previously unknown α,α-dichloro ketones **2**.

Treatment of 1-aryl-2,2-dichloro-1-alkanones **2** with sodium methoxide in methanol (2 N solution) at room temperature for a short time (1 h) afforded a mixture of isomeric α,α-dimethoxy ketones, namely 1-aryl-2,2-dimethoxy-1-alkanones **3** and 1-aryl-1,1-dimethoxy-2-alkanones **4**, the formation of which was explained via an epoxide intermediate **6** (Scheme II).[14] The ratio **3/4** was dependent on the substitution of the substrate (R, R'), the concentration of the nucleophile, and the temperature control.[14] In general the ratio varied between 40:60 for **3d/4d** and 70:30 for **3b/4d**. Acidic hydrolysis of this mixture of isomers **3** and **4** with 8 N aqueous hydrogen chloride solution provided pure 1-aryl-1,2-alkanediones **5** in high yields.

It is stressed that all steps of the pathway mentioned here proceed cleanly and that all intermediate compounds may be obtained in very high yields. Starting from ketones **1**, the three-step conversion into α,α-dichloro ketones **2** was exe-

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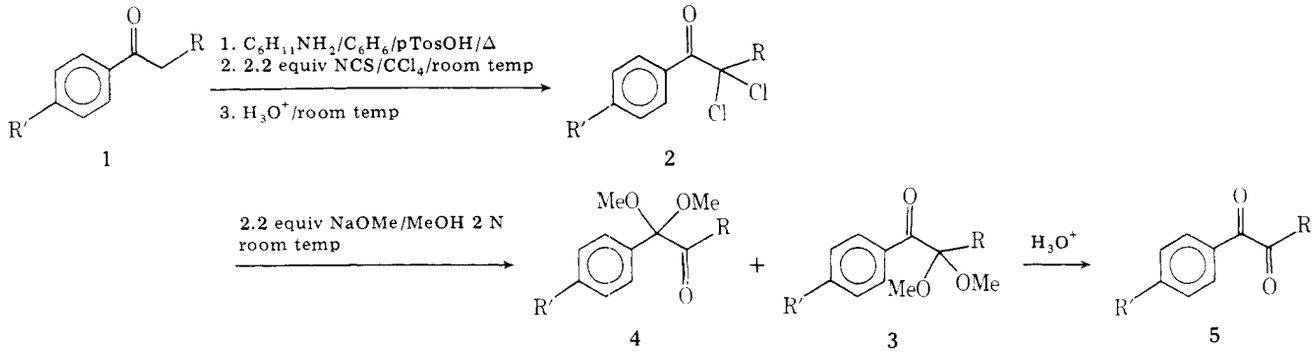
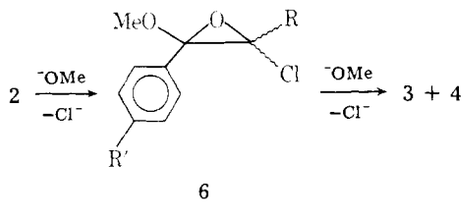
Scheme I



1 2 4 3 5

Scheme II



6

Table I. Synthesis[a] of 1-Aryl-1,2-alkanediones 5

	R	R′	% yield 1 → 2	% yield 2 → 3, 4	% yield 3, 4 → 5	Bp (5), °C (mmHg)
5a	Me	H	81	94	95	55–58 (0.2)[b]
b	Me	Cl	95	94	94	54–59 (0.03)[c]
c	Et	H	80	98	96	126–132 (12)[d]
d	*n*-Pr	H	90	95	98	60–61 (0.05)[e]

[a] Isolated yields (distillation in vacuo). [b] Lit. bp 55–56 °C (0.3 mmHg) (ref 6). [c] Lit. bp 140–144 °C (20 mmHg) (ref 15). [d] Lit. bp 74–76 °C (0.5 mmHg) (ref 6). [e] Lit. bp 82–84 °C (3 mmHg) (ref 6).

cuted in 80–95% isolated yield (after high vacuum distillation), while the reaction of **2** with NaOMe/MeOH gave α,α-dimethoxy ketones **3** and **4** in 94–98% isolated yield. Finally 1,2-diones **5** were obtained in 94–98% yield. The yields of the respective steps are tabulated below (Table I).

According to the results shown in Table I, the overall yields vary between 72 and 84%, taking into account that all intermediate compounds have been isolated by vacuum distillation.

It was possible to increase the yield of α-diketone **5** by carrying out the reaction sequence **1** → **5** without distillation of compounds **2**, **3**, and **4**. According to this straightforward procedure 1-phenyl-1,2-propanedione (**5a**) was prepared in 85% yield, thus giving rise to an increase in yield of 13% with respect to the results in Table I.

Except for the results described in this paper, almost no information is available on the reaction of α,α-dihalogenoaryl alkyl ketones with nucleophilic reagents. It has been reported[16,17] that the reaction of 2,2-dichloroacetophenones **2** (R = H; R′ = H or Ph) with sodium methoxide in methanol afforded 2,2-dimethoxyacetophenones **3** (R = H; R′ = H or Ph), while it has been later shown[18] that the reaction products involved in this reaction were their isomeric structures **4** (R = H), i.e., 2,2-dimethoxy-2-phenylacetaldehydes. The mistakenly attributed *p*-phenyl-2,2-dimethoxyacetophenone (**3**, R = H; R′ = Ph) could be further converted into *p*-phenylphenylglyoxal by acidic hydrolysis.[17]

The latter three papers mentioned reactions of 2,2-dichloroacetophenones, which are easily accessible.[19] The higher homologues **2** (R ≠ H) were previously unknown and are now generally available by the reaction sequence **1** → **2** outlined above. In contrast to 2,2-dichloroacetophenones **2** (R = H; R′ = H or Ph)[17,18] the methoxide-induced rearrangement of the higher homologues **2** (R = alkyl) via an intermediate epoxide gave rise to a mixture of isomeric α,α-dimethoxy ketones, which were hydrolyzed to the parent α-diketones.

In conclusion, the introduction of a carbonyl group in the α position of a carbonyl function conjugated with an aryl nucleus, according to the method described here, proceeds under relatively mild conditions and in high yields. The method, however, is limited to alkyl aryl ketones **1**. Nevertheless, the 1-aryl-1,2-alkanediones **5** thus available are important intermediates in organic syntheses (e.g., compound **5a** is the well-known precursor of ephedrine).

Experimental Section

All starting materials used were commercially available. IR spectra were recorded with a Perkin-Elmer Model 257 spectrophotometer. NMR spectra were measured with a Varian T-60 apparatus, while mass spectra were obtained from a GC–MS coupling of a Pye-Unicam gas chromatograph (model 104; SE 30; 1.5%; 1.5 m; He carrier gas) with an AEI MS 20 mass spectrometer. GLC analyses were performed with a Varian Model 920 gas chromatograph (SE 30; 5%; 3 m; H_2 carrier gas).

Synthesis of 1-Aryl-1,2-alkanediones 5. The experimental procedure used for the synthesis of 1-phenyl-1,2-pentanedione (**5d**) is representative of all other preparations. From 20.0 g (0.123 mol) of valerophenone (**1d**) there was obtained 24.9 g of 2,2-dichloro-1-phenyl-1-pentanone (**2d**; 90%), bp 73–79 °C (0.06 mmHg).[18] To 118.5 mL of 2 N sodium methoxide in methanol (0.237 mol, 2.2 equiv) cooled in a water bath was added dropwise with stirring 24.9 g (0.108 mol) of 2,2-dichloro-1-phenyl-1-pentanone (**2d**). After stirring 1 h at ambient temperature, methanol was evaporated under vacuum. Addition of 100 mL of water and extraction three times with diethyl ether yielded, after drying ($MgSO_4$) and evaporation, a clear oil which was distilled to afford 22.8 g of a pale yellow oil, bp 69–71 °C (0.05 mmHg) (40% **3d** and 60% **4d** as shown by NMR and GLC[20]). A solution of 22.8 g (0.1027 mol) of **3d** and **4d** in 200 mL of CCl_4 was vigorously stirred with 100 mL of concentrated HCl and 50 mL of water. After stirring overnight, the organic phase was isolated, washed with water, dried ($MgSO_4$), evaporated in vacuo, and distilled to give 17.7 g of 1-phenyl-1,2-pentanedione (**5d**), bp 60–61 °C (0.05 mmHg) (98% yield starting from **3d** + **4d**). The reaction sequence outlined in Scheme I was performed without purifying the intermediates by distillation. This synthesis was carried out on a large scale. Starting from 67.0 g of propiophenone (**1a**) there was obtained 63 g of 1-phenyl-1,2-propanedione (**5a**; 85% yield).

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Registry No.—**1a**, 93-55-0; **1b**, 6285-05-8; **1c**, 495-40-9; **1d**, 1009-14-9; **2a**, 57169-51-4; **2b**, 57169-53-6; **2c**, 66255-85-4; **2d**, 66255-86-5; **3a**, 38868-78-9; **3b**, 32763-17-0; **3c**, 57205-27-3; **3d**, 66255-87-6; **4a**; 57711-28-1; **4b**, 64743-30-2; **4c**, 66255-88-7; **4d**, 66255-89-8; **5a**, 579-07-7; **5b**, 10557-21-8; **5c**, 3457-55-4; **5d**, 20895-66-3.

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(20) Compound **4d** had a lower R_f value than compound **3d** (GLC). Benzoyl derivative **3d** showed a carbonyl stretching vibration at 1701 cm^{-1}, while isomer **4d** exhibited a much higher value at 1733 cm^{-1}. The NMR data of **3d** and **4d** supported the respective structural assignment. NMR (CCl_4) of compound **3d:** δ 0.83 (t, 3, J = 6 Hz, CH_3), 1.2 (m, 2, CH_2Me), 1.9 (t, 2, J = 7 Hz, $CH_2CC{=}O$), 3.25 (s, 6, $(OMe)_2$), 7.8–8.2 (m, 2, ortho aromatic protons), 7.2–7.5 (m, 3, meta and para aromatic protons). NMR (CCl_4) of compound **4d:** δ 0.76 (t, 3, J = 6.5 Hz), 1.30 (sextet, 2, CH_2Me), 2.40 (t, 2, $CH_2C{=}O$), 3.18 (s, 6, $(OMe)_2$), 7.2–7.6 (m, 5, C_6H_5). The mass spectral fragmentation further established the identity of acetals **3d** and **4d.** Mass spectrum of **3d**: *m/e* (rel abundance) no M^+, 117 (100), 105 (21), 77 (18), 71 (18), 57 (9), 43 (42). Mass spectrum of **4d:** *m/e* (rel abundance) no M^+, 151 (100), 105 (36), 91 (12), 77 (24), 59 (12), 51 (8), 43 (8).

Oxygen-18 Exchange between $[^{18}O]H_2O$ and H_2O_2 in the Presence of FSO_3H

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A peroxide molecule may undergo a variety of chemical reactions. The chemical versatility of peroxides is due to the fundamentally different cleavage modes available to the peroxide structure. While the free-radical chemistry of peroxide involving the homolytic cleavage of the weak O–O bond under a variety of conditions is well documented, the heterolytic cleavage of the O–O bond of peroxide is poorly understood in the mechanistic level.[1-3]

The unimolecular heterolytic cleavage of a peroxide molecule would generate RO^+ (oxenium ion) species, which is expected to be extremely reactive and for whose existence in solution there is no convincing evidence.[4] The bimolecular nucleophilic substitutions of peroxides with carbon, nitrogen, sulfur, phosphorus, and halide nucleophiles are well-known, and acid catalysis in these reactions has been observed.[2,3]

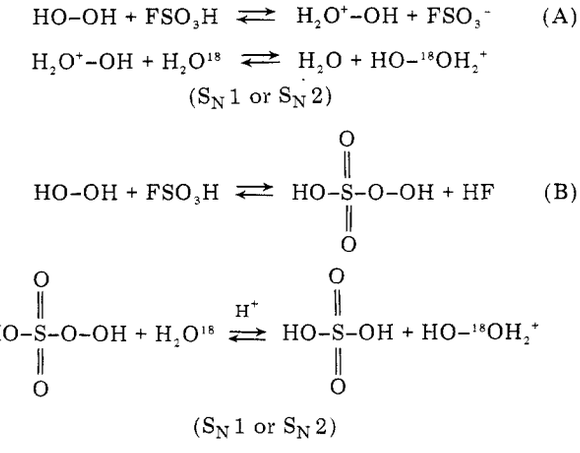
Although water is a reasonably good nucleophile in its attack on sp^3 carbon, its nucleophilic reaction with peroxides is not yet known. The lack of reactivity is normally explained in terms of the repulsion between the electrons on the incoming oxygen nucleophile and those on the peroxide oxygen.[2] Thus it was reported that no exchange occurs under acidic conditions between $[^{18}O]H_2O$ and either hydrogen peroxide,[5] alkyl hydroperoxides,[5] or peroxy acids[6] or between $[^{18}O]$ alcohols and hydrogen peroxide.[7] Similarly, hydrogen peroxide and alkyl hydroperoxides do not undergo oxygen isotope exchange with $^{18}OH^-$.[3]

Table I. $[^{18}O]$ Exchange of H_2O_2[f] with $[^{18}O]H_2O$[a]

run	H_2O_2, μL[b]	FSO_3H,[h] μL	$[^{18}O]H_2O$, μL[c]	Time, days	% exchange[d]
1	140	290	90	1.5	3.7
2	100	260	100	3.5	16.3
3	160	260	100	3.5	33.0
4	70	460[e]	50	3.0	<2.0

[a] Experiments were run by mixing the components in a Pyrex glass vessel under N_2 atmosphere at room temperature in the dark for the indicated time and by successively evacuating the system and treating with solid $KMnO_4$. O_2 evolved was trapped and analyzed for the ratio of *m/e* 34/32 by a mass spectrometer (Hitachi RMU-6 at 25 eV). Runs showing the presence of appreciable N_2 in the sample were discarded. [b] 90% H_2O_2. [c] Atom enrichment was determined to be 78% by mass spectrometric analysis. [d] The ratio of *m/e* 34/32 after correcting for the initial enrichment. The error limit of the measurement is about 1%. [e] Concentrated H_2SO_4 was used instead of FSO_3H. [f] Registry no. 7722-84-1. [g] Registry no. 14314-42-2. [h] Registry no. 7789-21-1.

Scheme I



In connection with our interest in oxygenase-catalyzed reaction mechanisms, we had an opportunity to reexamine the possibility of oxygen isotope exchange between $[^{18}O]H_2O$ and H_2O_2 in the presence of fluorosulfonic acid,[8] the strongest of the simple protonic acids, and wish to report the results of our work.

The results indicated by Table I demonstrate clearly that under these conditions water is a good enough nucleophile to cleave the O–O bond of hydrogen peroxide or its derivative. There appear to be two possible mechanisms for the exchange (Scheme I). Control experiments in which aliquots of the total mixture were analyzed for $SO^{16}O^{18}/SO^{16}O^{16}$ (*m/e* 66/64) prior to oxidation with $KMnO_4$ indicated that both concentrated H_2SO_4 and FSO_3H readily exchange oxygen isotope with $[^{18}O]H_2O$. However, only in the presence of FSO_3H does H_2O_2 exchange oxygen isotope with $[^{18}O]H_2O$. Therefore, it may be concluded that if mechanism (A) is operating, hydrogen peroxide is not significantly protonated by concentrated H_2SO_4, while if mechanism (B) is operating,[9] H_2O_2 and concentrated H_2SO_4 do not generate a significant concentration of persulfuric acid. Furthermore, distinguishing between the S_N1 and S_N2 processes is not possible based on the currently available information.

Acknowledgment. We are grateful to Research Corporation and Texas A&M University for their financial assistance and to Professor A. I. Scott for the gift of $[^{18}O]H_2O$ and encouragement.