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Note

Gas–liquid chromatography of substituted benzils and benzophenones

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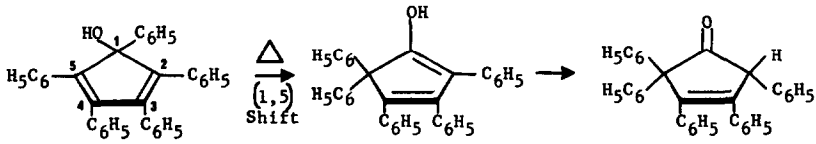
The thermally induced rearrangement of 1,2,3,4,5-pentaphenyl-2,4-cyclopentadienol (I) to 2,2,3,4,5-pentaphenyl-3-cyclopenten-1-one (IX) has been shown by Youssef and Ogliaruso[1] to be an example of a [1,5]-thermally allowed sigmatropic phenyl rearrangement. Our continuing investigations[1–3] have been directed toward characterization of electronic nature of the transition state of the rearrangement, first through a study of the effect of *p*-substituted phenyl at C-3 and C-4, and subsequently through a series of *p*-substituted phenyl migrating groups at C-1. Finally, a Hammett series of 2- and/or 5-(*p*- or *m*-substituted phenyl) cyclopentadienols can be used to characterize the effect of various substituents at the migration terminus (Fig. 1). Migration of phenyl in this system can take two directions, thus forming two products. The relative proportions of these isomers is an indication of the contribution of electronic effects at the migration terminus to the propensity of phenyl to migrate toward either site. Quantitative oxidative cleavage of the five-carbon ring would produce benzoic acid and carbon dioxide regardless of the substitution pattern, and a mixture of substituted benzils and benzophenones. The ratios of the secondary (oxidation) products would therefore indicate the ratio of the primary (rearrangement) products to each other.



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To evaluate potential oxidizing agents for this purpose and to execute this study, a chromatographic method was developed for the separation of not only benzil and benzophenone, but also for the anticipated analogues. Analytical methods have been reported for only a few of the compounds to be used in this study. Gas–liquid chromatography (GLC)[4] and high-performance liquid chromatography (HPLC)[5] have been used in the analysis of unsubstituted benzil, and GLC[6] has been used in

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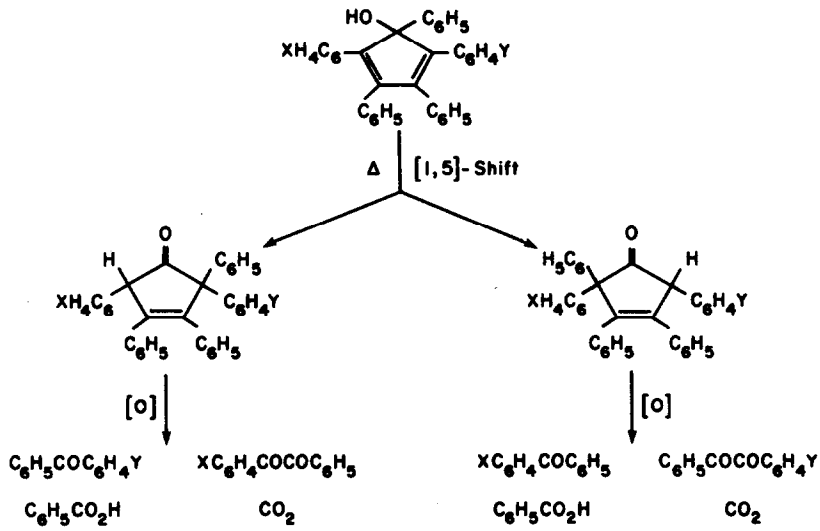

Fig. 1. Rearrangement and oxidation scheme. Cyclopentadienol No. (X,Y) = I, (H,H); II, (H,*p*-Br); III, (H,*p*-Cl); IV, (H,*p*-methoxy); V, (H,*p*-methyl); VI, (H,*m*-methoxy); VII, (*p*-methyl, *p*-Br); VIII, (*p*-methoxy,*p*-Cl).

the detection of *p*-chlorobenzophenone in the analysis of DDT-type compounds. For the related compound 4,4'-dichlorobenzophenone a number of thin-layer chromatography[7], GLC[7,8] and HPLC[9] methods have been developed, due to its relationship to the chlorinated hydrocarbon pesticides. For simultaneous separation of the mixtures of substituted benzils and benzophenones anticipated in this study, there are no previous reports.

EXPERIMENTAL

Chemicals and related materials

The substituted benzils were prepared by literature methods[10] and characterized by their melting points and spectroscopic data. Benzophenone, benzil, chromium trioxide, acetic anhydride and the substituted benzophenones were obtained from Aldrich (Milwaukee, WI, U.S.A.). 2,2,3,4,5-Pentaphenyl-3-cyclopenten-1-one was synthesized by the procedure of Youssef and Ogliaruso[1].

Chromatographic equipment

A Varian 1200 series gas chromatograph (Palo Alto, CA, U.S.A.) equipped with a flame ionization detector was used in this study. Chromatograms were recorded on a Model 285 Linear recorder (Linear Inst., Irvine, CA, U.S.A.).

Chromatographic column and conditions

A 6 ft. × 1/8 in. O.D. stainless-steel column packed with 5% OV-275 on 80–100 mesh Chromosorb W was used for all separations. Analyses were performed isothermally with injector temperature set at 210°C, column temperature 215°C, and detector maintained at 240°C, except in the methoxy-substituted cases. For *p*-me-

thoxy analogues temperature programming was used, 215–240°C at 2°C/min; for *m*-methoxy analogues the column temperature was programmed from 200–235°C at 4°C/min. Flow-rates were set at 30 ml/min (helium), 30 ml/min (hydrogen), and 300 ml/min (air).

GLC analysis of oxidation products

Into a 250-ml roundbottom flask equipped with a stirring bar and reflux condenser was placed 4.0 g (0.04 mol) of chromium trioxide and 100 ml of freshly distilled acetic anhydride. 2,2,3,4,5-Pentaphenyl-3-cyclopenten-1-one (2.31 g, 0.005 mol) was added to the solution with stirring. The reaction mixture was poured onto 100 ml of water and extracted with three 100 ml portions of benzene. The organic extract was then washed with three 100 ml portions of 5% sodium bicarbonate to remove benzoic acid and residual acetic acid. The organic solution was dried with anhydrous magnesium sulfate, filtered, and the benzene removed on a rotary evaporator to yield an orange tar for analysis. The product was transferred to a 25-ml volumetric flask, brought up to volume with chloroform, and aliquots for analysis were injected onto the GLC system described.

Standard curves for benzil and benzophenone were constructed by triplicate injection of standard solutions at four concentrations in the range of interest. All standard curves were linear and passed through the origin. The production of benzil and benzophenone from the oxidation were measured by comparing peak height multiplied by width at half-height against their respective standard curves. The product data represent the mean of triplicate runs.

RESULTS AND DISCUSSION

The retention times of the substituted benzils and benzophenones are listed in Table I. Two general patterns of elution should be noted. The first is that the ben-

TABLE I

ADJUSTED RETENTION TIMES FOR SUBSTITUTED BENZILS AND BENZOPHENONES ON 5% OV-275

Compound	*Retention time (min)*		
	*Isothermal**	*Programmed***	*Programmed****
Benzophenone	1.95	1.90	2.48
p-Methylbenzophenone	2.51	–	–
p-Chlorobenzophenone	3.08	2.85	–
p-Bromobenzophenone	4.78	–	–
Benzil	4.80	4.40	5.25
p-Methylbenzil	6.40	–	–
p-Chlorobenzil	6.60	5.60	–
p-Bromobenzil	10.0	–	–
p-Methoxybenzophenone	–	6.10	–
p-Methoxybenzil	–	12.0	–
m-Methoxybenzophenone	0.53	–	0.60
m-Methoxybenzil	12.0	–	9.38

* Column temperature 215°C.
** Programmed 215–240°C at 2°C/min.
*** Programmed 200–235°C at 4°C/min.

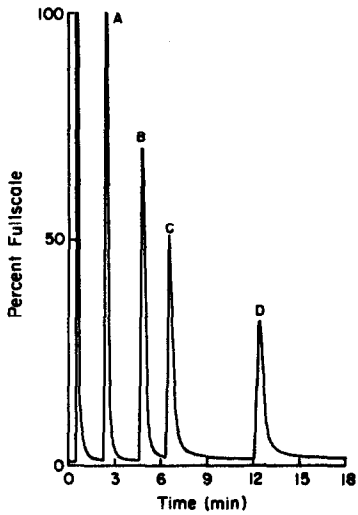

Fig. 2. GLC separation of (A) benzophenone, (B) benzil, (C) *p*-methoxybenzophenone, and (D) *p*-methoxybenzil on 5% OV-275. Temperature programmed 215–240°C at 2°C/min.

zophenones as a group have shorter retention times than the benzils, *i.e.*, each substituted benzophenone elutes earlier than its benzil counterpart. Secondly, a general elution order for the substituents exists for both the benzophenones and the benzils, H < *p*-methyl- < *p*-chloro- < *p*-bromo- < *p*-methoxy-. The *m*-methoxy substituent presents the only anomaly in that while it is the earliest eluting benzophenone, it is the penultimate benzil. It is not unexpected, however, that the chromatographic behavior of the *m*-isomers in this series would differ from that of the *p*-isomers. The *m*-methoxybenzophenone and the *m*-methoxybenzil have shorter retention times than their *p*-counterparts. Similarly, Abraham *et al.*[11] studying dichlorobenzophenone isomers found the 3,3′ and 3,4′ isomers had shorter retention times than the 4,4′ isomer.

Of the twelve compounds studied, all can be chromatographed within 12 min through the use of temperature programming. It must be noted that for the purposes for which this chromatographic system was developed, each oxidation mixture will contain only four products, *i.e.*, two benzils and two benzophenones (see Fig. 1). For example, oxidation of the cyclopentenone mixture produced by the rearrangement of cyclopentadienol(IV) will produce benzophenone, *p*-methoxybenzophenone, benzil and *p*-methoxybenzil. A representative chromatogram of this separation is shown in Fig. 2. In only one of these eight mixtures are two components unresolved, bromobenzophenone and benzil being inseparable. However, the ratio of the rearrangement products in this case can be determined from the other two components, bromobenzil and benzophenone, which are well-resolved.

Applications

The utility of the GLC system developed here for the separation of substituted benzils and benzophenones has been demonstrated. Using this system we evaluated the ability of diacetyl chromate to oxidatively degrade the unsubstituted prototype,

TABLE II

PRODUCT DISTRIBUTION FROM THE OXIDATION OF 2,2,3,4,5-PENTAPHENYL-3-CYCLOPENTEN-1-ONE WITH DIACETYL CHROMATE

The yield is expressed as the percentage (± standard deviation) of that compound which theoretically would be produced by quantitative cleavage of the 5-carbon ring.

Product	*Yield (%)*
Benzophenone	39.3 ± 1.5*
Benzil	40.0 ± 1.7*
Benzoic Acid	25.8 ± 1.6**

* GLC analysis.
** Isolated and recrystallized yield.

2,2,3,4,5-pentaphenyl-3-cyclopenten-1-one (IV). GLC analysis of the oxidation products (Table II) indicated equimolar production of benzil, benzophenone, and benzoic acid in a yield of approximately 40% of that which would theoretically be produced by quantitative cleavage of the five-carbon ring. Benzoic acid was identified by extraction and recrystallization from the product mixture before GLC analysis. Although the isolated yield of benzoic acid is lower than that of benzophenone and benzil, adjustment for physical losses by control extractions and recrystallizations indicate this yield to be equivalent to that of benzil and benzophenone.

The application of this system to the screening of other prospective oxidizing agents for their ability to effect quantitative cleavage of the five-carbon ring, as well as the determination of the rearrangement product ratios in the substituted cases will be published separately.

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REFERENCES

1 A. K. Youssef and M. A. Ogliaruso, *J. Org. Chem.*, 37 (1972) 2601.
2 A. K. Youssef and M. A. Ogliaruso, *J. Org. Chem.*, 38 (1973) 487.
3 G. B. Oldaker III, T. A. Perfetti and M. A. Ogliaruso, *J. Org. Chem.*, 45 (1980) 3910.
4 R. D. Schwartz and R. B. Mathews, *J. Chromatogr.*, 126 (1976) 113.
5 M. S. F. Ross, D. S. Lines, K. R. Brain and R. G. Stevens, *Anal. Biochem.*, 87 (1978) 267.
6 M. B. Abou-Donia, *Anal. Lett.*, 7 (1974) 313.
7 I. T. Glover and A. P. Minter, *J. Chem. Educ.*, 51 (1974) 685.
8 J. de D. Lopez Gonzales and C. Gonzales Gomez, *An. Quim.*, 67 (1971) 845.
9 J. W. Dolan and J. N. Seiber, *Anal. Chem.*, 49 (1977) 326.
10 E. R. Bockstahler and D. L. Wright, *J. Amer. Chem. Soc.*, 71 (1949) 3760.
11 M. H. Abraham, D. Huq, R. U. Koenigsberger and J. B. Rose, *J. Chromatogr.*, 206 (1981) 147.