ratio of their infrared absorbances was employed. For the pseudo-first-order reaction, the equation $B_t/A_t = 1/e^{kt} - 1 = e^{kt} - 1$ reduces to $\ln(1 - B/A) = kt$. A and B are absorbances read directly from the IR charts. The data for α-(*p*-methoxyphenyl)cinnamonitrile (**3i**) are typical (Table II).

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Registry No. **1** (Ar = *p*-chlorophenyl), 104-88-1; **1** (Ar = phenyl), 100-52-7; **1** (Ar = *p*-fluorophenyl), 459-57-4; **1** (Ar = *p*-anisyl), 123-11-5; **1** (Ar = *p*-tolyl), 104-87-0; **1** (Ar = *p*-(dimethylamino)phenyl), 100-10-7; **1** (Ar = α-naphthyl), 66-77-3; **1** (Ar = α-furyl), 98-01-1; **1** (Ar = α-thienyl), 98-03-3; **2** (Ar = *p*-chlorophenyl), 140-53-4; **2** (Ar = phenyl), 140-29-4; **2** (Ar = *p*-anisyl), 104-47-2; **3a**, 3695-94-1; **3b**, 3695-93-0; **3c**, 3695-92-9; **3d**, 2510-95-4; **3e**, 324-61-8; **3f**, 72030-11-6; **3g**, 6443-76-1; **3h**, 5432-07-5; **3i**, 5840-59-5; **3j**, 1222-61-3; **3k**, 6443-74-9; **3l**, 72030-12-7; **3m**, 2958-46-5; **3n**, 6582-06-5; **3o**, 65260-38-0; **3p**, 72030-13-8; **3q**, 72030-14-9; **3r**, 1207-91-6; **3s**, 72030-15-0; **3t**, 10280-99-6; **3u**, 72030-16-1; **3v**, 72030-17-2; **3w**, 72030-18-3; **4a**, 36770-81-7; **4b**, 5681-31-2; **4c**, 32970-79-9; **4d**, 3333-14-0; **4e**, 72035-44-0; **4f**, 5422-48-0; **4g**, 32970-77-7; **4h**, 32970-78-8; **4i**, 5840-58-4; **4j**, 72035-45-1; **4k**, 72035-46-2; **4l**, 72035-47-3; **4m**, 72035-48-4; **4n**, 72035-49-5; **4o**, 72035-50-8; **4p**, 72035-51-9; **4q**, 72035-52-0; **4r**, 1207-90-5; **4s**, 782-21-8; **4t**, 785-05-7; **4u**, 72035-53-1; **4v**, 72035-54-2; **4w**, 72035-55-3.

α-Bromoalkylides in Trisubstituted Olefin Synthesis. Regiospecific Entry to 4-Bromo-1,4-dienes

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Interest continues to be shown in synthetic routes to stereo- and regiodefined trisubstituted olefins,[1] mainly because of the occurrence in nature of many compounds of this class having significant biological activity. Recent reports of novel synthetic methods for 1,4-dienes, including some of this class,[2] prompt us to disclose our own results in this area.

We have previously shown[3] that triphenylphosphonium dibromomethylide (**1**) can be successfully alkylated with methyl and ethyl bromides to give the salts **2a** and **2b** (eq 1). Treatment of these salts with *n*-BuLi in THF at low

$$\underset{\mathbf{1}}{Ph_3\overset{+}{P}-\overset{-}{C}Br_2} + RBr \rightarrow \underset{\substack{\mathbf{2a},\ R = Me\\ \mathbf{2b},\ R = Et\\ \mathbf{2c},\ R = CH_2CH{=}CH_2}}{Ph_3\overset{+}{P}-CBr_2R\ Br^-} \quad (1)$$

$$\mathbf{2} + n\text{-BuLi} \xrightarrow[-40\ ^\circ C]{THF} \underset{\mathbf{3}}{Ph_3\overset{+}{P}-\overset{-}{C}BrR} + n\text{-BuBr} \quad (2)$$

$$\mathbf{3} + R'CHO \rightarrow \underset{\mathbf{4},\ R' = \text{alkyl, aryl}}{R'CH{=}CBrR} \quad (3)$$

temperature (eq 2) gives rise to α-bromoalkylides **3**, products of halogen–metal exchange. As indicated in eq 3, these intermediates react with aldehydes in Wittig fashion, furnishing the corresponding trisubstituted bromo olefins **4**, often with high stereoselectivity.

Table I. Products from the Reaction of Triphenylphosphonium 1-Bromo-3-butenylide with Aldehydes

aldehyde	bromo olefin	*Z*:*E*[a] ratio	% yield[b]
$C_6H_{13}CHO$	$C_6H_{13}CH{=}CBr\text{-}CH_2CH{=}CH_2$ (**6**)	36:64	78
PhCHO	$PhCH{=}CBrCH_2CH{=}CH_2$ (**7**)	20:80	68

[a] Diastereomers easily separable by GC on 5% SE30. The *E* isomer was identified as the major component in each case from the NMR appearance of the olefinic proton on the trisubstituted double bond. In (*E*)-**6**, the proton appears at lower field than in the *Z* isomer, as would be anticipated from its position *cis* to the vicinal Br. In addition, the same proton also displays the *smaller* allylic coupling. *Transoid* allylic couplings in related bromo olefins are smaller than *cisoid* couplings (see ref 3). [b] Obtained after chromatography on silical gel; purity (GC) exceeded 95% in both cases.

It occurred to us that, depending upon the availability of salt **2c**, the method might be extended to regiospecific synthesis of unsymmetrical functionalized 1,4-dienes. As it turned out, when **1** was alkylated with allyl bromide, the desired precursor **2c**, (1,1-dibromo-3-butenyl)triphenylphosphonium bromide, could be isolated as a white solid, mp 187–189 °C, in 60–68% yield.

It should be mentioned that attempts to extend these alkylations to the *dichloromethylide*[4] system, i.e., $PH_3P^+-{}^-CCl_2$, were unsuccessful, and the only alkylated products obtained in this case were the salts which arise via direct alkylation of the phosphine, viz., **5**. This result sheds further light on the mechanism of tetrahalomethane–triphenylphosphine reactions, which have merited some previous investigation.[5a,b] For the corresponding difluoromethylide,[5b] it has been demonstrated that stable ylide solutions are provided by a mobile equilibrium of the type shown in eq 4. In the present case, the existence of

$$\begin{aligned} &Ph_3P + BrCX_3 \rightarrow Ph_3\overset{+}{P}-CX_3\ Br^-\\ &Ph_3\overset{+}{P}-CX_3\ Br^- + Ph_3P \rightleftharpoons Ph_3\overset{+}{P}-\overset{-}{C}X_3 + Ph_3PXBr \quad (4)\\ &\qquad\qquad\qquad\quad \downarrow RBr \quad \downarrow RBr\\ &\qquad\qquad\quad Br^-\ Ph_3\overset{+}{P}-R \quad Ph_3\overset{+}{P}-CX_3R\ Br^-\\ &\qquad\qquad\quad\ \mathbf{5} \end{aligned}$$

a similar equilibrium whose position depends critically upon the nature of the halogen accommodates the results. While for X = Cl, as for F, the equilibrium must lie predominantly to the left, for X = Br, the absence of products corresponding to **5** requires it to lie far to the right.

When **2c** was treated with BuLi followed by 1 equiv of heptanal and the resulting pale yellow solution worked up in the usual way (see Experimental Section), a 78% yield of 4-bromoundeca-1,4-diene was obtained. The details of this reaction, as well as that occurring with benzaldehyde, are summarized in Table I.

Compounds **6** and **7** appear to be the first reported examples of this class, possibly because a regiospecific entry to this group has not hitherto been possible. The stereoselectivities in these reactions are somewhat lower than that observed with the corresponding α-bromoethylide—they are also quite strikingly reversed. As Table I shows, while both **6** and **7** are preferentially formed with

(1) See for example: (a) D. E. Van Horn and E. Negishi, *J. Am. Chem. Soc.*, **100**, 2252 (1978); (b) E. Negishi, N. Okukado, A. O. King, D. E. Van Horn, and B. I. Spiegel, *ibid.*, **100**, 2254 (1978).

(2) (a) R. O. Hutchins and N. R. Natale, *J. Org. Chem.*, **43**, 2299 (1978); (b) C. Cahiez, A. Alexakis, and J. F. Normant, *Synthesis*, 528 (1978); (c) G. L. Van Mourik and H. J. J. Pabon, *Tetrahedron Lett.*, 2705 (1978).

(3) R. H. Smithers, *J. Org. Chem.*, **43**, 2833 (1978).

(4) From the reaction of bromotrichloromethane and triphenylphosphine, see B. A. Clement and R. L. Soulen, *J. Org. Chem.*, **41**, 556 (1976).

(5) (a) For a review of the tetrachloromethane–tertiary phosphine system, see: R. Appel, *Angew, Chem., Int. Ed. Engl.*, **14**, 801 (1975); (b) D. G. Naae, H. S. Kesling and D. J. Burton, *Tetrahedron Lett.*, 3789 (1975).

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E stereochemistry, the opposite was demonstrated earlier for α-bromoethylide reactions, which showed high stereoselectivity for Z isomers.

Experimental Section

^{1}H NMR spectra were recorded at 60 MHz with a Hitachi Perkin-Elmer R20B instrument (tetramethylsilane as internal standard, $CDCl_3$ as solvent). Analytical GLC was performed on a Varian Aerograph Series 1800 preparative instrument using a 10 ft × 0.25 in. column packed with 10% SE30 on Chromosorb W support, operated at 115 °C. Elemental analyses were performed by the Australian Microanalytical Service, CSIRO, Victoria, Australia.

Materials. Triphenylphosphine, carbon tetrabromide, tetrahydrofuran, and dichloromethane[6] were purified as reported previously.[3] Allyl bromide was freshly distilled and stored over 5A molecular sieves.

Synthesis of Phosphonium Salt 2c. A typical preparation is as follows. Into a 250-mL three-necked flask fitted with a mechanical stirrer, low temperature thermometer, and pressure-equalized dropping funnel was introduced a solution of purified carbon tetrabromide (33.2 g, 0.1 mol) in *dry* dichloromethane[6] (100 mL) under a nitrogen blanket. While the mixture was stirred and dry ice–acetone cooled (−5 to 0 °C), a solution of triphenylphosphine (52.4 g, 0.2 mol) in dry dichloromethane was rapidly added (10 min) via the dropping funnel and stirring continued until a heavy precipitate appeared (~15 min). After the flask contents were cooled to −30 °C, allyl bromide (14.5 g, 0.12 mol) in dry dichloromethane (20 mL) was added dropwise to the gently stirred solution (30 min) and stirring then continued overnight at 2 °C. The product, a cream-colored suspension in a pale yellow solution, was poured with rapid stirring into aqueous potassium bicarbonate (120 mL of a 2 M solution; 0.24 mol). When the gassing had finished, a small volume of ethanol (~25 mL) was added to completely dissolve the solid, the organic layer was separated and dried ($MgSO_4$), and the solvent was removed. Trituration of the resulting solid material with benzene (100 mL) to remove Ph_3PO followed by dissolution of the crude **2c** in the minimum volume of CH_2Cl_2–EtOH (9:1) and reprecipitation with hot ethyl acetate furnished 34.0 g (61%) of **2c**, mp 187–189 °C. A further crop of ~4.0 g of product, mp 179–182 °C, was obtained on concentration of the mother liquor. Drying was effected at 65 °C in a vacuum oven (~0.5 mmHg): ^{1}H NMR δ 3.4 (2 H, m), 5.2–6.0 3 H, m), 7.7–8.2 (15 H, m). Anal. Calcd for $C_{22}H_{20}Br_3P$: C, 47.60; H, 3.6; Br, 43.20. Found: C, 47.6; H, 3.6; Br, 43.4.

Procedure for Wittig Reactions. As described previously, ylide generation was carried out by dropwise addition of n-BuLi in hexane to a 10% excess of **2c** suspended in THF mechanically stirred at −40 °C. After the mixture was stirred an additional 30 min at this temperature, the aldehyde in a small volume of THF was added at −55 to −60 °C. Workup involved slow warming to room temperature, being stirred for 30 min, filtration, concentration, extraction (hexane), and column chromatography (silica gel, hexane eluent). Removal of solvent rendered **6** and **7** as colorless oils.

4-Bromoundeca-1,4-diene (6): ^{1}H NMR δ 0.7–1.5 (11 H, m), 3.1 (2 H, d, J = ~6 Hz), 4.8–5.2 (2 H, m), 5.4–5.9 (1 H, m), 5.5 (1 H, t, $J_{allylic}$ > 1 Hz, Z isomer), 5.8 (1 H, t, $J_{allylic}$ < 1 Hz, E isomer). Anal. Calcd for $C_{11}H_{19}Br$: C, 57.2; H, 8.3; Br, 34.6. Found: C, 56.9; H, 8.2; Br, 33.4.

1-Phenyl-2-bromo-1,4-pentadiene (7): ^{1}H NMR δ 3.15–3.4 (2 H, d, J = ~6 Hz), 4.9–5.3 (2 H, m), 5.5–6.2 (1 H, m), 6.7 (1 H, brs, Z isomer), 6.95 (1 H, brs, E isomer), 7.1–7.3 (5 H, brs).

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Registry No. 2c, 71974-98-6; **6**, E isomer, 71987-45-6; **6**, Z isomer, 71974-99-7; **7**, E isomer, 71975-00-3; **7**, Z isomer, 71975-01-4; carbon tetrabromide, 558-13-4; triphenylphosphine, 603-35-0; allyl bromide, 106-95-6; $C_6H_{13}CHO$, 111-71-7; PhCHO, 100-52-7.

(6) Final drying over 3A molecular sieves gives superdry solvent: D. R. Burfield, G. H. Gan, and R. H. Smithers, *J. Appl. Chem. Biotechnol.*, **28**, 23 (1978).

N-(Ethoxycarbonyl)phthalimide. An Improved Procedure

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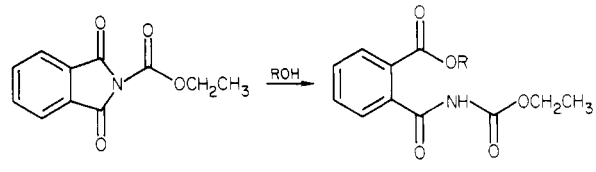
N-(Ethoxycarbonyl)phthalimide (1) has been known for some time as a reagent for the *N*-phthaloylation of primary amino groups.[1] The mild conditions under which it causes N-phthaloylation offers advantages over other methods.[2] Heating with phthalic anhydride can cause racemization of amino acids[2a,b] and formation of byproducts when used with amino alcohols.[2c] The advantages of protecting amino groups by formation of phthaloyl derivatives, compared, for example, with the use of benzylcarbonyl derivatives, also has been recognized for some time.[3] Yet Nefkens' reagent, **1**, has not achieved wide use as recently pointed out.[4] Low yields were experienced in the use of **1** to N-phthaloylate 2-aminoethanol compared with the phthalic anhydride fusion method.[5] In the course of our work on the asymmetric alkylation of polymer-bound imines,[6] we encountered difficulties in the N-phthaloylation of amino alcohols through the use of **1**. When we attempted to prepare **1** by Nefkens' procedure,[1] only impure product in low yields was obtained.

The procedure of Nefkens et al.,[1] involving the reaction of phthalimide and ethyl chloroformate in the presence of triethylamine, in our hands afforded **1**, after the purification steps described,[1] in 43% yield[7] which was contaminated to the extent of 10% with phthalimide which appears to cocrystallize with **1**.[8] The extent of contamination was indicated both by the NMR spectrum of the product mixture and by separation and isolation of the components through fractional crystallization of the mixture from chloroform.

The earlier report[1] states that **1** exhibited no reactivity towards water, alcohols, and acids. Ethanol was the



1 **2**

solvent used[1] for the purification of **1** by successive recrystallizations. We have found that **1** reacts in hot alcohols and is converted to the corresponding ethyl *N*-[2-(alkoxycarbonyl)benzoyl]carbamates, **2**.

(1) (a) G. H. L. Nefkens, G. I. Tesser, and R. J. F. Nivard, *Recl. Trav. Chim. Pays-Bas*, **79**, 688 (1960); (b) G. H. L. Nefkens, *Nature (London)*, **185**, 309 (1960).

(2) (a) Y. F. Shealy, C. E. Opliger, and J. A. Montgomery, *J. Pharm. Sci.*, **57**, 757 (1968); (b) H. Sato, T. Kusumi, K. Inaye, and H. Kakisawa, *Bull. Chem. Soc. Jpn.*, **49**, 2815 (1976); (c) Z. W. Wicks, Jr., and G. Chen, *J. Org. Chem.*, **44**, 1244 (1979).

(3) J. C. Sheehan and V. S. Frank, *J. Am. Chem. Soc.*, **71**, 1857 (1949).

(4) S. O. DeSilva and V. Snieckus, *Can. J. Chem.*, **56**, 1621 (1978).

(5) S. Wolfe and S. K. Hasan, *Can. J. Chem.*, **48**, 3572 (1970).

(6) P. M. Worster, C. R. McArthur, and C. C. Leznoff, *Angew. Chem., Int. Ed. Engl.*, **18**, 221 (1979).

(7) While Nefkens et al.[1] reported 80% yield, it apparently was based on the weight of solid material obtained before the recrystallizations described in their procedure.

(8) The melting point of the product containing 10% phthalimide was the same as that reported[1] (79–80 °C; lit.[1] mp 80 °C).

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