the role of the porphyrin and imidazole in modulating the iron populations cannot be neglected.[2]

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Camphorae: Chiral Intermediates for the Total Synthesis of Steroids[†]

Sir:

A major effort has been devoted to the synthesis and utilization of C,D intermediates in the total synthesis of steroids.[1-4] Since the biological activity of steroids is restricted to one en-

Scheme I

Scheme II
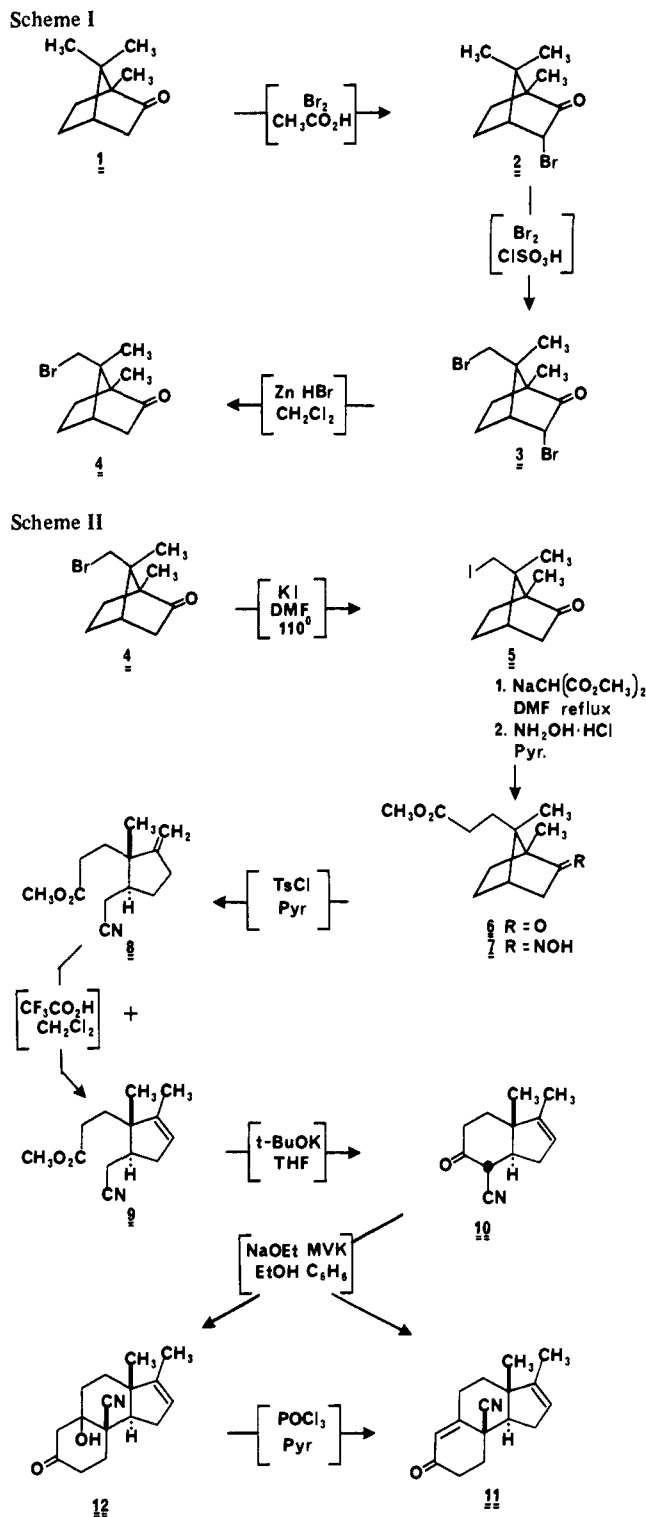
antiomer, a major problem has been the development of a practical method for the production of such intermediates in chirally pure form. Recently, several ingenious solutions to this important problem have been realized and involve the employment of remarkably efficient asymmetric induction reactions.[5] Such methodology is obviously a more desirable method for achieving the necessary chirality than classical resolution by derivatization.[6] We now wish to present a fundamentally different approach to the total synthesis of chirally pure steroids, which takes advantage of (a) the natural chirality of (−)-camphor (1) and (b) its topology.

Direct functionalization of camphor[7] at the C-9 methyl group has been known for over 80 years.[8] Hence, preparation of (−)-π-bromocamphor[9] (4) can be accomplished[8a,d,e] effi-

ciently and *with complete retention of chirality*[8a,b] by the sequence 1–4 (Scheme I).

Attempts at the direct displacement of (−)-π-bromocamphor (4) or its 1,3-dioxolane derivative with dimethyl malonate anion failed. Therefore, we prepared (−)-π-iodocamphor (5) using a threefold excess of anhydrous potassium iodide[10] in freshly distilled dimethylformamide (DMF) at 110 °C in nearly quantitative yield (Scheme II). In contrast to the bromo derivative, reaction of the latter intermediate with 10 equiv of the sodium salt of dimethyl malonate in refluxing DMF (17 h) provided (−)-keto ester 6[11,12] (60%). The displacement was accompanied by concommitant decarbomethoxylation (presumably via attack of displaced iodide on the initially formed diester[13]). Oximation of 6 was carried out by standard means and the resultant (+)-oximino ester (7)[14] exposed to *p*-toluenesulfonyl chloride in pyridine to induce Beckmann fragmentation[16] (70%). The resultant mixture of double bond isomers (8 and 9) readily converged to the more stable endocyclic (−)-cyano ester 9 when treated with anhydrous trifluoroacetic acid. Cyclization of 9 to (+)-cyano ketone 10 proceeded unidirectionally in 70% yield[11] using potassium *tert*-butoxide in tetrahydrofuran. The use of similar C,D intermediates in the total synthesis of steroids has been dealt with elsewhere.[4c,d] For example, in a preliminary study on the subsequent deployment of 10, we have found that it reacts readily with methyl vinyl ketone[17] to afford a mixture of tricyclenone 11 and hydroxy ketone 12 and that the latter substance can be dehydrated to 11 when exposed to POCl₃-pyridine. Further studies to utilize these intermediates in the total synthesis of several steroids is under active investigation.

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An Experimental Determination of "Bonding Charge" in Carbon–Carbon Bonds

Sir:

Many attempts have been made to understand the nature of the chemical bond by correlating bond length with theoretically derived quantities such as bond order, electronegativity, hybridization, and ionic character.[1] In this communication we provide estimates of the amount of charge in various C–C bonds and a correlation between bonding charge and bond length, both quantitites being experimentally derived.

In recent years accurate x-ray (and neutron) diffraction measurements together with the development of various computational techniques[2] have led to a significant progress in determining the electron density distribution in a chemical bond. Electron density difference maps[3] may be exploited for the calculation of derived quantities as net molecular or ionic charges, dipole and quadrupole moments, atom populations, and "bonding charge" in bonds. Very little has been done in this area, which is still in the stage of definitions and development of methods.[4]

The "net bonding charge"—the amount of charge which migrates to the region between bonded atoms on formation of a molecule—may be defined as the excess charge which accumulates between bonded atoms over the amount that would have occurred in these regions as a consequence of superposition of spherical atoms.

An estimate of the "bonding charge", as defined above, may be obtained from the deformation maps[3] by integrating the positive difference density over the volume of the bond. In cases where the excess density in the bond is completely surrounded by a surface of zero deformation density,[4c] the region of integration is uniquely defined; where the bonding peak is not confined to the region between two bonded atoms, e.g., peaks of adjacent bonds merge,[6b] the number of electrons obtained is affected somewhat by the choice of the integration boundaries.[7]

We have estimated the number of "bonding electrons" in various C–C bonds of several molecules whose electron-density distributions were mapped[4b,c,5,6] using accurate x-ray data measured at low temperatures[4b,c,6,8] and room temperature.[9] The bond lengths varied between 1.26 and 1.57 Å.[10a] The standard deviation in the charge was estimated to be 0.03 e in tetraphenylbutatriene.[10b]

Figure 1, which presents a plot of bonding charge vs. bond length, summarizes the results of this study. Three principal conclusions may be drawn from this plot, which almost falls on a smooth line. (a) The number of "bonding electrons", as defined above, is relatively small; only a fraction of one electron accumulates in the bond; 0.1–0.3 e[11] were found in the range (1.57–1.26 Å) investigated.[12] (b) It is possible to correlate the number of bonding electrons with bond length in C–C bonds belonging to entirely different molecules varying widely in