J. Org. Chem. 1980, 45, 3291-3295

8.1-kcal/mol observed value (we will use ΔG values as being more accurate even though ΔH should be used). For the low-temperature process, the molecular mechanics calculations predict a population ratio of 4:96 vs. the 10:90 observed ratio and a barrier of 5.1 kcal vs. the 5.5-kcal observed value.

Molecular mechanics appears to be a useful tool in assessing conformational possibilities in monofluorosubstituted hydrocarbons.

Experimental Section

General Methods. NMR spectra were obtained on a Varian XL-100 spectrometer operating at 94.1 MHz. Proton-noise decoupling was used. Spectra were run on the 5000-Hz sweep at a sweep rate of 20 Hz/s. Temperatures were measured by replacing the sample with a Doric digital thermometer. Chemical shifts were measured relative to internal CHF_2Cl and converted to the δ scale ($CFCl_3$) by adding −71.7 ppm.

Fluorocyclooctane. A stable, HF-free sample of fluorocyclooctane was prepared by adding a solution of 5.12 g (0.04 mol) of cyclooctanol in 4 mL of CCl_3F to a stirred solution of 5 mL (0.04 mol) of (diethylamino)sulfur trifluoride (DAST)[13] in 40 mL of CCl_3F cooled to −78 °C. The reaction mixture was warmed to 0 °C and poured into water. The organic layer was separated, washed with water, 5% $NaHCO_3$, and water again, and dried ($MgSO_4$). Distillation gave 4.5 g of a colorless liquid composed of 80% fluorocyclooctane and 20% cyclooctene (by ^1H NMR and GLC analysis); bp <25 °C (0.8 mm).

A sample of fluorocyclooctane was also prepared (without isolation) in propene solution by reaction of DAST with cyclooctanol in propene at −78 °C. However, solutions prepared in this manner must be kept cold and used immediately because the HF present causes an autocatalytic decomposition of the fluorocyclooctane.

Acknowledgment. The fluorine NMR spectra were obtained by Wendy John.

Registry No. Fluorocyclooctane, 53731-16-1; cyclooctanol, 696-71-9.

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[13] W. J. Middleton, *J. Org. Chem.*, **40**, 574 (1975); U.S. Patent 3914265 (1975).

Synthesis and ^3H NMR Analysis of [1,4-$^3H_2$]Benzene: A Natural Source of Tritiated Phenylium Cations

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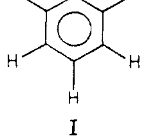
Multicurie amounts of [^3H_x]benzene (x = 1, 2) were prepared by ^3H_2O decomposition of 1,4-phenylenebis[bromomagnesium]. After purification, the radio gas chromatographic analysis of the [^3H_x]benzene fraction revealed less than 0.1% radioactive impurities (mostly [^3H]bromobenzene). Isotopic analysis by ^3H NMR spectroscopy showed that the major component (56 mol %) of the [^3H_x]benzene mixture is [1,4-$^3H_2$]benzene (overall yield ca. 23%), the remainder being mainly [^3H]benzene. An interesting long-range inverse heavy-isotope effect on the ^3H NMR chemical shifts of the two radioactive products has been observed and its possible cause considered.

Introduction

Although there are many well-established solvolytic methods for generating carbocations, to date dediazoniation of benzenediazonium ion salts is the only route for the production of phenylium ions (I) in solution.[1]



I

This limitation is one of the main reasons for the long time span between Waters' original proposal[2] for the existence of I and the very recent systematic solution[3] and gas-phase[4] studies that have gathered persuasive evidence for the occurrence of I and that have provided information on its nature.[5]

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[1] (a) H. B. Ambroz and T. J. Kemp, *Chem. Soc. Rev.*, **8**, 353 (1979); (b) L. R. Subramanian, M. H. Hanack, L. W. K. Chang, M. A. Imhoff, P. v. R. Schleyer, F. Effenberger, W. Kurtz, P. J. Stang, and T. E Dueber, *J. Org. Chem.*, **41**, 4099 (1976).

[2] W. A. Waters, *J. Chem. Soc.*, 266 (1942).

[3] (a) I. Szele and H. Zollinger, *J. Am. Chem. Soc.*, **100**, 2811 (1978); (b) Y. Hashida, R. G. M. Landells, G. E. Lewis, I. Szele, and H. Zollinger, *ibid.*, **100**, 2816 (1978); (c) J. F. Bunnett and C. Yijima, *J. Org. Chem.*, **42**, 639 (1977); (d) T. J. Broxton, J. F. Bunnett, and C. H. Paik, *ibid.*, **42**, 643 (1977); (e) R. G. Bergstrom, R. G. M. Landells, G. H. Wahl, Jr., and H. Zollinger, *J. Am. Chem. Soc.*, **98**, 3301 (1976); (f) C. G. Swain, J. E. Sheats, and K. G. Harbison, *ibid.*, **97**, 783 (1975); (g) C. G. Swain, J. E. Sheats, D. G. Gorenstein, and K. G. Harbison, *ibid.*, **97**, 791 (1975); (h) C. G. Swain, J. E. Sheats, and K. G. Harbison, *ibid.*, **97**, 796 (1975); (i) C. G. Swain and R. J. Rogers, *ibid.*, **97**, 799 (1975); (j) K. R. Brower and J. S. Chen, *ibid.*, **87**, 3396 (1965).

[4] (a) M. Speranza, M. D. Sefcik, J. M. S. Henis, and P. P. Gaspar, *ibid.*, **99**, 5583 (1977); (b) H. W. Leung, H. Ichikawa, Y. H. Li, and A. G. Harrison, *ibid.*, **100**, 2479 (1978).

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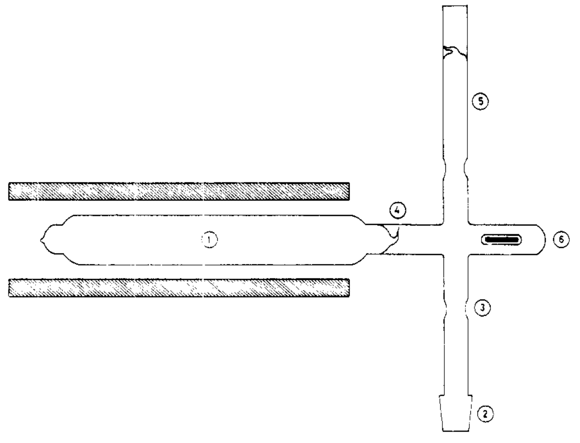
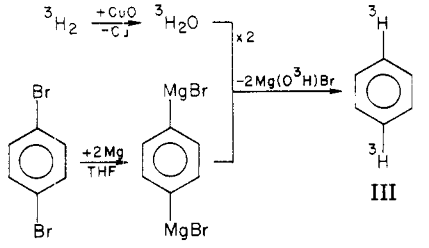


Figure 1. Apparatus for the preparation of ^3H_2O.

We believe that an alternative and more versatile method for generating arylium ions, either in the gaseous[6] or in the condensed[7] phase, is to utilize the β decay of multitritiated arenes. Organic compounds containing two or more tritium atoms in the same molecule have been used in recent years in a variety of kinetic studies as the precursors of labeled carbocations of precisely defined structures.[8]

In the present paper we report on the first preparation of [$^3H_2$]benzene, containing the two ^3H atoms in preestablished positions. The spontaneous β^- decay of one of them makes these compounds natural generators of tritiated phenylium cations,[6,7] whose reactivity and selectivity (as well as their inherent tendency to undergo rearrangement[3g,9]) can be conveniently investigated by using conventional tracer techniques.

The preparation of [1,4-$^3H_2$]benzene (III), regarded as a suitable precursor of tritiated phenylium cation, was carried out by the route shown in eq 1. Special attention was paid to keeping the reaction vessel as dry as possible as the presence of traces of water would lead to benzene molecules with lower ^3H content. Thus, in order to find out the best experimental conditions for the radioactive synthesis, blank runs using fully deuterated water were carried out and the products analyzed by GC–mass spectroscopy.



II

III

(1)

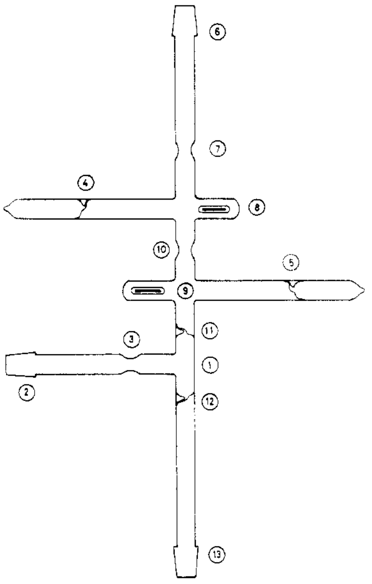


Figure 2. Apparatus for the preparation of [$^3H_2$]benzene.

Experimental Section

Materials. Tritium gas with a stated purity of 98 mol % was purchased from the Radiochemical Centre, Amersham, England, the major impurities being ^{3}HH and ^{3}He. Merck Co. provided pro-analysi copper oxide (99 mol %), magnesium turnings for Grignard synthesis (99.5 mol %), and Uvasol deuterium oxide (99.75 mol %). 1,4-Dibromobenzene was obtained from Fluka AG and purified by preparative GLC (99.5 mol %) before use.

Apparatus and Procedure. Preparation of ^3H_2O. A. The Pyrex apparatus for the preparation of ^3H_2O is shown in Figure 1. According to a well-established procedure,[10] a suitable amount (10 Ci) of tritium gas was oxidized with CuO in (1) at 450 °C for 14 h. After cooling, the apparatus was connected to a vacuum line via joint (2) and thoroughly degassed and sealed off at the constriction (3). Then, the break-seal (4) was broken with the pyrex-enclosed magnetic hammer (6), allowing the formed ^3H_2O to condense from (1) into the liquid-nitrogen cooled vial (5), which then was sealed off. This procedure was duplicated in order to prepare two vials containing approximately the same amount of ^3H_2O (nominal activity ~10 Ci each).

B. Preparation of [$^3H_2$]Benzene. The apparatus employed for the preliminary ^2H_2O blank runs and for the preparation of [$^3H_2$]benzene is illustrated in Figure 2. 1,4-Phenylenebis[bromomagnesium] (II) was prepared according to Odabashyan's procedure,[11] using a 1:2 molar ratio of 1,4-dibromobenzene to magnesium in tetrahydrofuran (THF) as solvent. A portion of the reaction mixture containing 6×10^{-5} mol[12] of II was introduced into region (1) of the vessel, and the THF was removed by connecting the apparatus to a vacuum line by joint (2) and gently warming the Grignard solution for 30 min at 10^{-3} torr. After the solution cooled, the constriction (3) was sealed off. The two vials containing ^3H_2O were next joined to the side arms (4) and (5). The apparatus was then connected to a vacuum line via joint (6), thoroughly degassed, and sealed off at constriction (7). Afterwards, the break-seal in (4) was broken with the Pyrex-enclosed magnetic hammer (8), allowing the ^3H_2O contained in (4) to diffuse into (9) and expose all the glass surfaces to exchange for 3 h. The exchanged water was then recovered into the liquid nitrogen cooled arm (4) and sealed at (10). Then, the ^3H_2O contained in the second vial (5) was allowed to condense onto the liquid nitrogen cooled

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[5] (a) A. Cox, T. J. Kemp, D. R. Payne, M. C. R. Symons, and P. Pinot de Moira, *J. Am. Chem. Soc.*, **100**, 4779 (1978); (b) A. Cox, T. J. Kemp, D. R. Payne, M. C. R. Symons, D. M. Allen, and P. Pinot de Moira, *J. Chem. Soc., Chem. Commun.*, 693 (1976); (c) H. W. Leung and A. G. Harrison, *J. Am. Chem. Soc.*, **101**, 3168 (1979).

[6] (a) T. A. Carlson, *J. Chem. Phys.*, **32**, 1234 (1960); (b) S. Wexler, G. A. Anderson, and L. A. Singer, *ibid.*, 417; (c) K. Okuno, K. Yoshihara, and T. Shiowawa, *Radiochimica Acta*, **25**, 21 (1978).

[7] V. D. Nefedov, E. N. Sinotova, M. V. Korsakov, and E. G. Alekseev, *Radiokhimiya*, **15**, 635 (1973).

[8] (a) F. Cacace, *Adv. Phys. Org. Chem.*, **8**, 79 (1970); (b) F. Cacace, "Interaction between Ions and Molecules", P. Ausloos, Ed., Plenum Press, New York, 1975; (c) P. Giacomello and M. Speranza, *J. Am. Chem. Soc.*, **99**, 7918 (1977); (d) P. Giacomello and M. Schuller, *Radiochimica Acta*, **24**, 111 (1977); (e) F. Cacace and P. Giacomello, *J. Am. Chem. Soc.*, **99**, 5477 (1977); (f) F. Cacace and P. Giacomello, *J. Chem. Soc., Perkin Trans. 2*, 652 (1978); (g) F. Cacace and M. Speranza, *J. Am. Chem. Soc.* **101**, 1587 (1979).

[9] J. D. Dill, P. v. R. Schleyer, and J. A. Pople, *J. Am. Chem. Soc.*, **99**, 1 (1977).

[10] (a) F. Cacace and M. Schuller, *J. Labelled Compd.*, **11**, 313 (1975); (b) G. Ciranni and A. Guarino, *ibid.*, **2**, 198 (1966).

[11] G. V. Odabashyan, I. V. Romashkin, and L. E. Pashchenko, *Zh. Obshch. Khim.*, **41**, 2454 (1971).

[12] The nominal molarity of the bifunctional Grignard reagent was determined by the amount of benzene formed from its hydrolysis (see Table I, run a).

Table I. Mass Spectrometric Analysis of Deuterated Benzenes from Deuteriolysis of 1,4-Phenylenebis(bromomagnesium)

run	II, mmol	^2H_2O, mmol	absolute[a] $C_6H_{6-x}{}^2H_x$ yield, %	relative abundances[b] of $C_6H_{6-x}{}^2H_x$, %		
				$x = 0$	$x = 1$	$x = 2$
a	0.06	277 (H_2O)	100 (92)	100		
b	0.06	277	100 (92)	4	8	88
c	0.06	0.163	84 (77)	12	15	73
d	0.06	0.163[c]	85 (78)	6	7	87
e	0.06	0.146[c]	77 (71)	13	7	80

[a] Values in parentheses refer to the absolute $C_6H_{6-x}{}^2H_x$ yields based on the starting 1,4-dibromobenzene. [b] Values corrected for background contributions. [c] After preliminary washing of the reaction vessel with the same amount of ^2H_2O.

(II) powder by opening the break-seal tips (5) and (11) in succession. The reaction mixture was allowed to warm up and stay for 1 h at room temperature.

Immediately afterward, the radioactive suspension was diluted with an excess (1 mL) of high-purity benzene (99.9 mol %) in order to wash out and recover any organic product adsorbed on the walls of the apparatus. The benzene solution was finally bulb-to-bulb distilled on a vacuum line.

Radiochemical Analysis. A small fraction of the crude reaction product was analyzed by radio gas chromatography. The analysis was carried out by using a C. Erba Model C gas chromatograph, equipped with a 2.5-m long, 4-mm i.d., 80/100-mesh Porapak Q column, operated at 180 °C, with helium as the carrier gas at a flow rate of 50 mL min^{-1}. The effluent from the column, diluted with CH_4 (50 mL min^{-1}), was fed into a flow-ionization chamber kept at 160 °C, coupled with a Cary 401 vibrating-reed electrometer and a strip-chart recorder.

Purification of Crude Product. The crude reaction product was purified by preparative gas chromatography on two different columns [25% Apiezon L on 60/80-mesh Chromosorb W (4 m, 70 °C) and 80/100-mesh Porapak Q (2.5 m, 180 °C)] until the recovered benzene fraction displayed a constant specific activity by liquid scintillation counting on a Nuclear Chicago Mark II spectrometer. The radiochemical purity of the benzene fraction was further checked by radio gas chromatography.

Isotopic Analysis. The isotopic composition of the deuterated benzene from the blank runs was determined by GC–MS methods, using a HP 5980A quadrupole mass spectrometer. The isotopic distribution was calculated from the pertinent ion abundances after suitable background corrections from blank analyses on samples of C_6H_6 were carried out under identical conditions. Fourier-transform ^3H NMR spectroscopy was employed to determine the isotopic distribution in the [^3H_x]benzene fraction. Thus, an 80-mCi sample of [^3H_x]benzene in C_6H_6 was analyzed on a Bruker WP200 NMR spectrometer operating at 213.47 MHz. Theoretical calculations of the ^3H NMR spectra of [^3H]-, [1,2-$^3H_2$]-, [1,3-$^3H_2$]-, and [1,4-$^3H_2$]benzenes and their mixtures have been performed, using a Laocoon type program,[13] with input data from [1-^{13}C]benzene,[14] corrected for the appropriate magnetogyric ratio.

Storage. The high specific activity of $C_6H_4{}^3H_2$, ca. 58 000 Ci mol^{-1}, causes rapid self-radiolytic decomposition when the product is stored in the pure state.

Dilution with a large excess (2 × 10^2:1) of inactive benzene in the presence of O_2, as a radical scavenger, minimizes the destructive effects of [^3H_x]benzene self-radiolysis, giving rise to easily removable radioactive side products (e.g., biphenyl).[7]

Thus, the ^3H NMR isotopic analysis of initially pure [^3H_x]benzene, diluted with benzene to a molar ratio of 1:2 × 10^2 and stored for 2 months, did not appear substantially different from a qualitative run carried out on the freshly prepared and GLC purified sample.

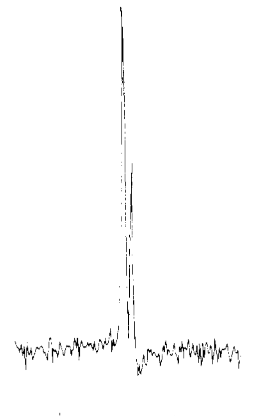

Figure 3. Resolution-enhanced proton-decoupled 213.47-MHz FT ^3H NMR spectrum of the [^3H_x]benzene (x = 1, 2) mixture.

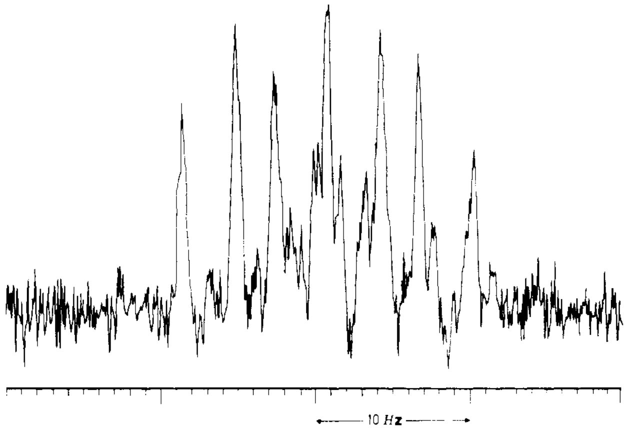

Figure 4. Resolution-enhanced proton-coupled 213.47-MHz FT ^3H NMR spectrum of the [^3H_x]benzene (x = 1, 2) mixture.

Results and Discussion

Table I gives the relative abundances of $C_6H_{6-x}{}^2H_x$ (x = 0, 1, 2) from deuterolysis of II using different ^2H_2O:II molar ratios. It is apparent from the table that conversion of the Grignard reagent to deuterated benzene is very high in all cases and that the highest yield of [$^2H_2$]benzene is obtained either by using a very large excess of ^2H_2O (run b) or by preliminary ^2H_2O washing of the reaction vessel before addition of a slight excess (~150%) of the deuterated reactant (run d). Owing to the difficulty of preparing large quantities of fully tritiated water, we decided to use the latter procedure in the radioactive run. Apart from a certain activity due to residual tritiated water, the radioactive product distribution obtained from ^3H_2O decomposition of II is given in Table II, together with the radiochemical purity of the [^3H_x]benzene fraction after gas chromatographic purification.

We conclude that the proposed synthetic method gives rise to the formation of highly pure [^3H_x]benzene (>99.9 mol %), together with [^3H]bromobenzene as the most abundant (0.04 mol %) impurity.

To meet the original purpose of preparing [$^3H_2$]benzenes with the two radioactive atoms in preestablished positions (see Introduction) and, therefore, making them suitable as decay source of tritiated phenylium ions, we submitted a portion (80 mCi) of the purified [^3H_x]benzene sample to Fourier-transform ^3H NMR analysis, with the twofold purpose of determining the actual $C_6H_5{}^3H$:$C_6H_4{}^3H_2$ molar ratio and the mutual position of the ^3H atoms in the [$^3H_2$]benzene fraction.

The proton-decoupled ^3H NMR spectrum shown in Figure 3 (8.2-s acquisition time, 42° nutation angle,

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(13) S. Castellano and A. A. Bothner-by, *J. Chem. Phys.*, **41**, 3863 (1964).

(14) P. Diehl, H. Bosiger, and H. Zimmermann, *J. Magn. Reson.*, **33**, 113 (1979).

Table II. Radiochemical Yields of Tritiated Products from ^3H_2O Decomposition of 1,4-Phenylenebis(bromomagnesium)[a]

products	activity, mCi	relative yields of products, %	yields relative to total ^3H_2O employed, %	% of theoretical yield
$(C_2C_4)\text{-}^3H$[b]	1.8 (5×10^{-2})	0.13 (~0)	0.02 (~0)	0.06 (~0)
THF-^3H[c]	3.0 (0.2)	0.22 (0.02)	0.03 (2×10^{-3})	0.11 (0.7×10^{-2})
$BrC_6H_4{}^3H$	4.4 (0.5)	0.32 (0.04)	0.04 (5×10^{-3})	0.16 (1.8×10^{-2})
$C_6H_{6-x}{}^3H_x$	1348.1 (1152.2)	99.32 (99.93)	13.48 (11.52)	48.15 (41.14)
Σ	1357.3 (1153.0)	99.99 (99.99)	13.57 (11.53)	48.48 (41.16)

[a] Values in parentheses pertain to activities measured after gas chromatographic purification of the [^3H_x]benzene sample. [b] Unidentified C_2, C_4 hydrocarbons. [c] Exchanged residual Grignard solvent.

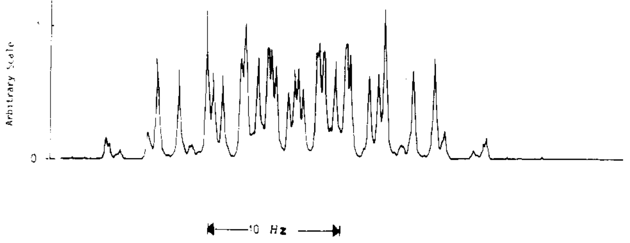

Figure 5. Calculated 213.47-MHz ^3H NMR spectrum of [^3H]-benzene.

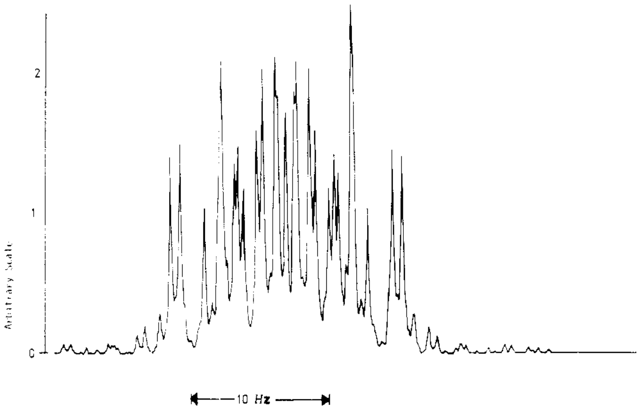

Figure 6. Calculated 213.47-MHz ^3H NMR spectrum of [1,2-$^3H_2$]benzene.

1000-Hz sweep width) reveals the presence of two tritiated compounds. Comparison of the resolution-enhanced (by convolution difference) proton-coupled spectrum shown in Figure 4 (3528 scans, 16.4-second acquisition time, 24° nutation angle, 500-Hz sweep width) with calculated ^3H NMR spectra (Figures 5–8) for [^3H]-, [1,2-$^3H_2$]-, [1,3-$^3H_2$]-, and [1,4-$^3H_2$]benzenes indicates that the most abundant isomer in the radioactive sample is [1,4-$^3H_2$]benzene. We therefore assign the larger peak at lower field in the proton-decoupled spectrum (Figure 3) to [1,4-$^3H_2$]benzene, with the higher field (less intense) peak attributed to [^3H]benzene.

This assignment is substantiated by the correspondence between the resolution-enhanced experimental spectrum (Figure 4) and that calculated by using a 44:56 distribution of [^3H]benzene to [1,4-$^3H_2$]benzene, taken from the proton-decoupled spectrum and shown in Figure 9.

It is quite surprising to observe a chemical-shift difference (0.004 ppm) between [^3H]benzene and [1,4-$^3H_2$]-benzene. This represents the first chemical-shift isotope effect observed through five bonds that cannot be ascribed to steric interactions.[15] Even more surprising is the fact that the resonance of the doubly tritiated isomer is at a

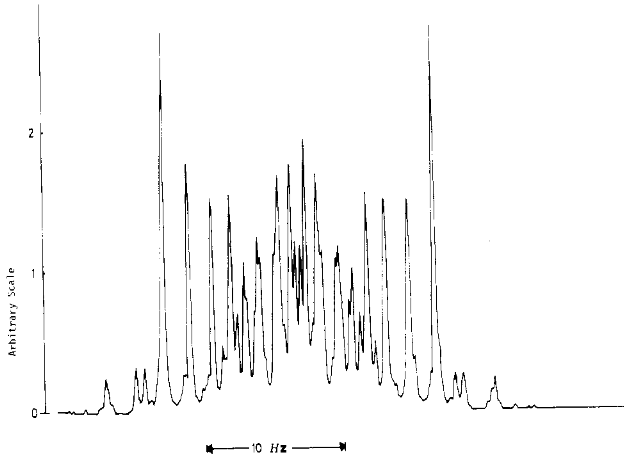

Figure 7. Calculated 213.47-MHz ^3H NMR spectrum of [1,3-$^3H_2$]benzene.

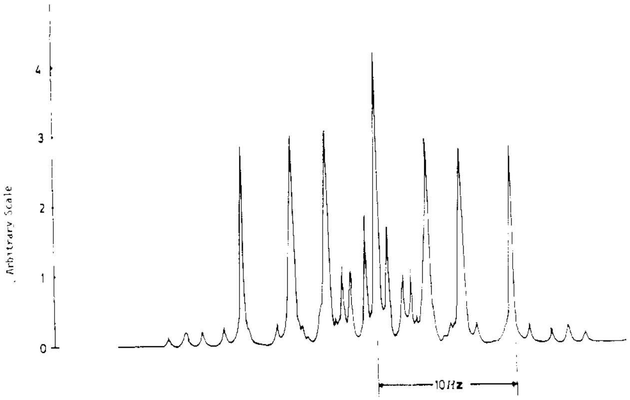

Figure 8. Calculated 213.47-MHz ^3H NMR spectrum of [1,4-$^3H_2$]benzene.

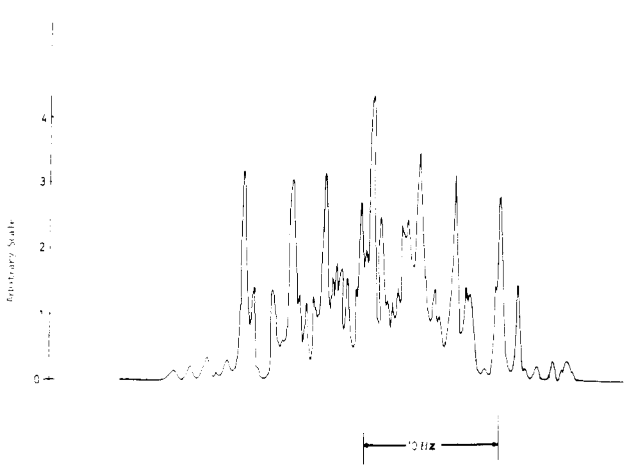

Figure 9. Calculated 213.47-MHz ^3H NMR spectrum of a 44:56 [^3H]benzene–[1,4-$^3H_2$]benzene mixture.

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(15) (a) F. A. L. Anet and A. H. Dekmezian, *J. Am. Chem. Soc.*, 101, 5449 (1979); (b) A. L. Allred and W. D. Wilk, *J. Chem. Soc. D*, 273 (1969).

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lower field, since it is known that the introduction of a heavier isotope into a compound usually induces shifts to higher field in neighboring nuclei.[16] All current theories based on vibrational effects predict an upfield shift due to heavy-isotope introduction, significantly decreasing with the number of bonds.[16] A possible explanation of the present results might be found in the occurrence of vibronic effects induced by the heavier isotope in tritiated benzenes, as indicated by the different ortho–ortho vs. meta–meta H–H distance measured in [^{3}H]benzene.[17] Perhaps the symmetry differences between [1,4-$^{3}H_{2}$]benzene and [^{3}H]-, [1,2-$^{3}H_{2}$]-, and [1,3-$^{3}H_{2}$]benzenes might play some role. The assessment of these effects deserves further investigation.

Finally, comparison of the product distribution in the [$^{3}H_{x}$]benzene sample ($C_6H_5{}^3H/C_6H_4{}^3H_2 \simeq 1$) with that measured in the blank $^{2}H_2O$ runs ($C_6H_5{}^2H/C_6H_4{}^2H_2 \simeq 0.1$) suggests that the observed discrepancy is mainly attributable to the isotopic purity of the starting water. In conclusion, we indicate in the proposed synthetic method a convenient route for obtaining [1,4-$^{3}H_{2}$]benzene with high chemical purity. For the specific purpose of the present study, the isotopic purity of the [1,4-$^{3}H_{2}$]benzene is also quite satisfactory, but, if necessary, it can be further improved by using a much larger excess of isotopically pure $^{3}H_2O$.

Acknowledgment. We thank Dr. R. Ehrenkaufer and Dr. A. P. Wolf at the Brookhaven National Laboratory for their active interest in this work.

Registry No. II, 2425-81-2; III, 73728-29-7; [^{3}H]benzene, 3508-32-5; $^{3}H_2O$, 14940-65-9; $BrC_6H_4{}^3H$, 61862-35-9; [1,2-$^{3}H_{2}$]benzene, 73713-15-2; [1,3-$^{3}H_{2}$]benzene, 73713-16-3; C_6H_6, 71-43-2; $C_6H_5{}^2H$, 1120-89-4; $C_6H_4{}^2H_2$, 25323-71-1; 1,4-dibromobenzene, 106-37-6.

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[16] (a) H. Batiz-Hernandez and R. A. Bernheim, *Prog. Nucl. Magn. Reson. Spectrosc.*, **3**, 63–85 (1967); (b) C. J. Jameson, *J. Chem. Phys.*, **66**, 4983 (1977); (c) A. D. Buckingham and W. Urland, *Chem. Rev.*, **75**, 113 (1975).

[17] T. C. Wong and L. J. Altman, *J. Magn. Reson.*, **37**, 285 (1980).

Acidities of Water and Simple Alcohols in Dimethyl Sulfoxide Solution

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A method is described for determining equilibrium constants between the indicators triphenylmethane and diphenylmethane (DH) and the solvent Me$_2$SO; pK_a values of 32.1 and 35.1 are assigned to DH and Me$_2$SO, respectively. This method is then extended to the determination of pK_a values for MeOH, EtOH, *i*-PrOH, and H_2O in Me$_2$SO, taking into account the leveling effect of the solvent, homohydrogen bonding ("homoconjugation"), and ion pairing. The pK_a values of the simple alcohols in Me$_2$SO were found to increase progressively with molecular size: MeOH (29.0) < EtOH (29.8) < *i*-PrOH (30.2). The pK_a of H_2O in Me$_2$SO is higher (31.4), but is lower than that of *t*-BuOH (32.2).

The observation that the intrinsic acidities of the simple alcohols in the gas phase follow the order *t*-BuOH > *i*-PrOH > EtOH > MeOH and that the gas-phase acidity of water is *much* less than that of methanol attracted attention, in part, because the solution acidity order was generally believed to be in the opposite direction.[1] Actually, the solution order is rather dependent on medium. In aqueous solution the statistically corrected order is MeOH > EtOH ≃ H_2O, MeOH being only 0.4 pK unit more acidic than EtOH or H_2O. (The pK_a's in water are 15.50, ~15.9, and 15.75, respectively.[2]) The relative acidities in benzene are MeOH > EtOH, *i*-PrOH > *t*-BuOH, the "pK_a's" being 16, 18, 18, and 19, respectively.[3a] It is uncertain, however, that this is a true acidity order because the position of the equilibria used to determine the order in this medium (eq 1) could be as dependent (or

$$\mathrm{RO{-}H + R'O^{-}Na^{+} \xrightleftharpoons{C_6H_6} RO^{-}Na^{+} + R'O{-}H} \qquad (1)$$

more so) on the relative stabilities of the ion pairs (or aggregates), RO^-Na^+ and $R'O^-Na^+$, as on the relative acidities of ROH and R'OH. In isopropyl alcohol the relative order MeOH > H_2O > EtOH > *i*-PrOH has been observed, the ΔpK_a's relative to *i*-PrOH being 1.7, 1.2, and 1.1, respectively; *t*-BuOH was too weakly acidic to measure.[3b] Ion association no doubt occurs to some extent also in isopropyl alcohol, since the dielectric constant is rather low ($\epsilon = 18.3$) and the counterion was Na^+, which is now known to ion pair strongly with alkoxide ions.[8]

In dimethyl sulfoxide solution a somewhat different relative acidity order, MeOH > EtOH > *t*-BuOH, H_2O,[4] has been reported. The acidities were determined by a potentiometric method[4a] and an overlapping indicator method.[4b,c] The pK_a's reported are actually about 2 pK_a units too low[5] because of (a) problems with the potentiometric method[5] and (b) the decision to anchor the overlapping indicator scale on the pK_a of *p*-nitroaniline determined by the H_- method in aqueous media.[4c] The acidities of alcohols in Me$_2$SO, as determined from enthalpies of deprotonation, are in the same order, but the

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