Communications to the Editor

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The Effect of the Alkaline Earth Salts on the NMR Spectrum of Phenols

The phenolic hydroxyl and *ortho* proton resonances in ^1H NMR spectrum showed the downfield shifts on addition of alkaline earth salts to phenols in $(CD_3)_2SO$. Among alkaline earth salts, anhydrous magnesium chloride caused the strongest downfield shifts, both for the hydroxyl and phenolic *ortho* protons. The selective shifts of phenolic *ortho* proton resonances due to anhydrous magnesium chloride promise to be generally useful in aiding the structure elucidation of natural phenols.

While studying the interaction of morphine with calcium chloride, we found in the ^1H NMR spectrum that the signals for the phenolic hydroxyl proton and the aromatic proton *ortho* to the hydroxyl group moved downfield on addition of alkaline earth salts to phenols in $(CD_3)_2SO$. To illustrate this effect, we cite the case of the hydroxyl and aromatic proton resonances in the NMR spectrum of eugenol shifted by magnesium chloride (*cf.* Fig. 1).

Fig. 2 and Fig. 3 show the effect of alkali and alkaline earth salt concentration on the hydroxyl and aromatic proton chemical shifts of eugenol at 38±2°. The data show the similarity to the shift data observed in analogous study of methanol and assigned to ion pair formation.[1] It is therefore suggested that the downfield shifts for the phenolic hydroxyl and *ortho* protons may be assigned to ion pair or complex ion formation.

In analogy with the work on methanol, the shifts due to metal chlorides and calcium salts are downfield in the order of $Mg^{2+}>Ca^{2+}\approx Sr^{2+}$ and of $Cl^->Br^-$, respectively. Further, anhydrous salts cause greater shifts than hydrous salts. Anhydrous magnesium chloride is accordingly the most suitable salt to use for observing the downfield shifts caused by alkaline earth salts.

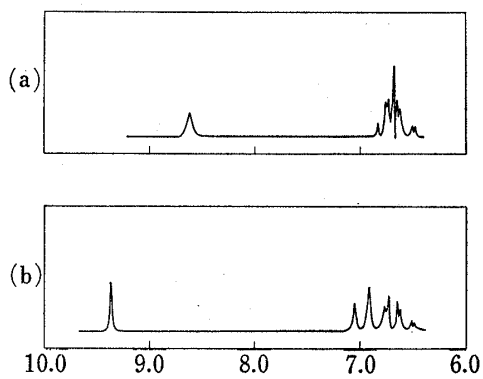

Fig. 1. (a) The Hydroxy and Aromatic Proton Resonances in 60 MHz ^1H NMR Spectrum of Eugenol in $(CD_3)_2SO$ Chemical Shifts in δ Units (ppm) Relative to Internal Me_4Si
(b) The ^1H NMR Spectrum of Eugenol in $(CD_3)_2SO$ after the Addition of $MgCl_2$ (1.6 mole ratio to eugenol)

We have studied twenty-three phenolic compounds other than eugenol and found that the phenolic *ortho* proton resonance shift is from 4 cps to 20 cps and the hydroxyl resonance is from 20 cps to 54 cps at 1 mole ratio of magnesium chloride to phenol. The magnitude of the shift in polyhydric phenols is smaller than that in monohydric phenols.

These shifts are weaker than those caused by the known shift reagent, $Eu(DPM)_3$, which is not a suitable shift reagent for phenols as it decomposes slowly in the presence of phenolic hydroxyl group.[2] Moreover, these alkaline earth salts change the splitting pattern of aromatic resonances. Our studies using magnesium chloride promise therefore to be generally useful in aiding the structure elucidation of natural phenols.

1) R.M. Hammaker and R.M. Clegg, *J. Mol. Spectry.*, **22**, 109 (1967).
2) J.K.M. Sanders and D.H. Williams, *Chem. Comm.*, **1970**, 422.

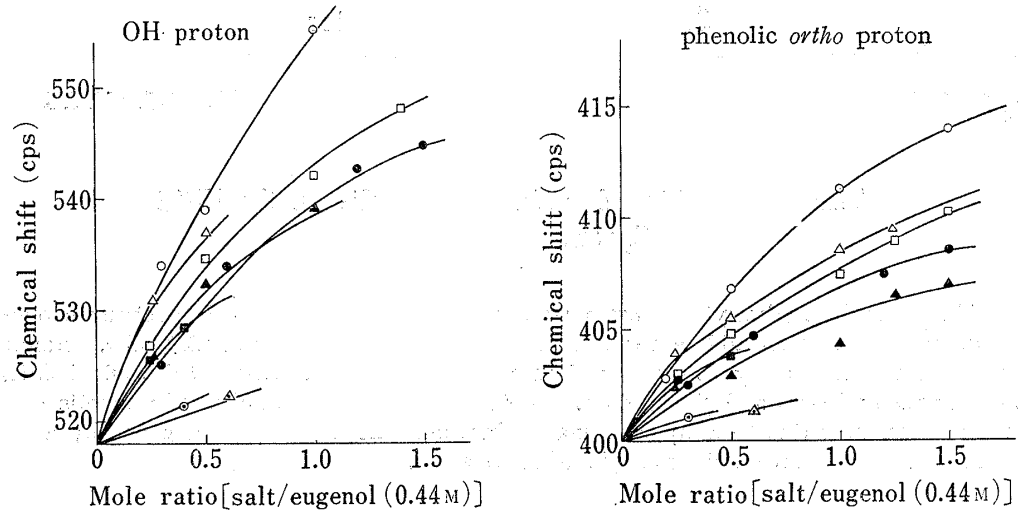

Fig. 2. Hydroxy and Phenolic *ortho* Proton Chemical Shift as a Function of Moles Chloride Salt/Mole Eugenol

—○—: $MgCl_2$, —□—: $CaCl_2$, —●—: $CaCl_2 \cdot 2H_2O$, —▲—: $SrCl_2 \cdot 6H_2O$, —■—: $BaCl_2 \cdot 2H_2O$
—⊙—: KCl, —△—: NaCl, —△—: $MgCl_2 \cdot 6H_2O$

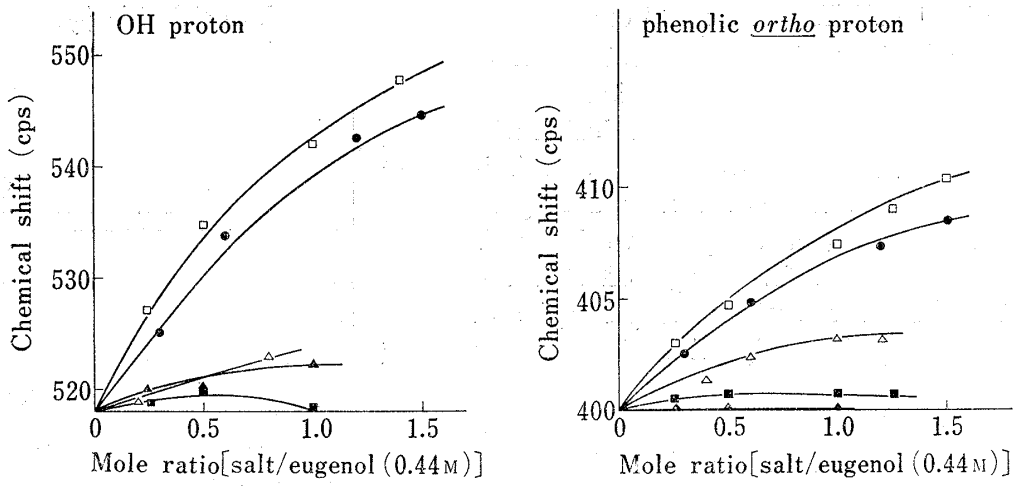

Fig. 3. Hydroxy and Phenolic *ortho* Proton Chemical Shift as a Function of Moles Calcium Salt/Mole Eugenol

—□—: $CaCl_2$, —●—: $CaCl_2 \cdot 2H_2O$, —△—: $CaBr_2 \cdot 3H_2O$, —▲—: $Ca(NO_3)_2 \cdot 4H_2O$, —■—: $CaI_2 \cdot 4H_2O$

Osaka College of Pharmacy
2-10-65, Kawai,
Matsubara, Osaka

HIDEO YAMAGUCHI
ATSUSHI NUMATA
EIICHI UEMURA

Faculty of Pharmaceutical Sciences,
Nagasaki University
1-14, Bunkyocho, Nagasaki

HIROSHI KANETO

Faculty of Pharmaceutical Sciences,
Kyoto University
Sakyo-ku, Kyoto

AKIRA YOKOYAMA

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