EPR Study of the Alimemazine Cation Radical

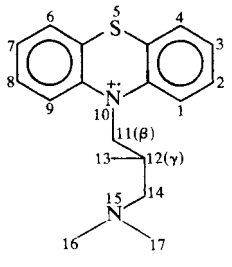
F. López-Rupérez, J. C. Conesa and J. Soria*
Instituto de Catálisis y Petroleoquímica, CSIC, Serrano 119, Madrid (6), Spain

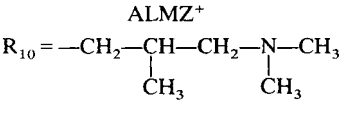
The EPR spectrum of alimemazine cation radicals ($ALMZ^+$) in a perchlorate single crystal has been studied at 293 K. Since strong exchange interactions between the radicals did not allow the determination of the hyperfine splitting constants, the spectrum of an $ALMZ^+$ solution, frozen at 77 K, was also studied. The results, checked by computer simulation, indicate orthorhombic symmetry of the g(2.0075, 2.0059, 2.0023) and hfs ($A^N_{xx} = 3.6$ G; $A^N_{yy} = 2.0$ G; $A^N_{zz} = 15.6$ G) tensors.

INTRODUCTION

The cation radical salts of phenothiazine and its derivatives have aroused great interest over the last few years because of their pharmacological properties, which depend on the type of side chain, and also because of their characteristics as organic semiconductors. Several papers have been devoted to the study by EPR of these cationic derivatives in solution,[1,2] but there has not been much work on their salts in the solid state.[3] The study by EPR of single crystals is limited, not only by the difficulty in obtaining good samples, but also because the information provided is restricted by the strong exchange interaction between the paramagnetic radicals.

We have previously studied[2] the influence of temperature, between 233 and 333 K, on the EPR parameters of the alimemazine cation radical ($ALMZ^+$) in solution (Scheme 1).





Scheme 1

The experimental results, checked by simulation of the spectra, indicate that the β-protons which are close to C-11 are not equivalent, and that two conformations of the side chain, which have very different populations, must be considered. At 233 K the contribution of the less populated conformation is small, and the EPR spectrum can be interpreted as being due to the other conformation. In this work $ALMZ^+$ has been studied in the solid state, in order to determine the EPR parameters of the main conformation which cannot be calculated from the spectra in solution. A single crystal has been used to obtain the g tensor, and the spectrum of dilute, strongly immobilized $ALMZ^+$ from a sulphuric acid solution, frozen at 77 K, has been used in order to determine the hyperfine coupling tensor components.

EXPERIMENTAL

The sample of ALMZ in neutral form was provided by Specia (Rhône–Poulenc Pharma), for the study of $ALMZ^+$ in single crystal and powder forms; the cation radical was obtained following the method of Merkle and Discher,[4] in which the perchlorate was the final product.

The EPR spectra of the single crystal, at different orientations in relation to the external magnetic field, were obtained using a goniometer and a hexahedral sample holder that allows the rotation of the single crystal in three planes which are mutually perpendicular. Since the small size of the $ALMZ^+$ single crystal prevented it from being placed in a known position relative to its crystallographic axes, the sample holder edges have been considered as an arbitrary axis system[1–3] and the single crystal, although forming unknown angles with this system, is jointly affected by the rotations.

For each one of the three axes 1, 2 and 3, a set of g effective values was measured by rotating the sample around the axis at 10° intervals, the origin of the rotation ($\theta = 0°$) being taken with one of the edges of the sample holder nearly parallel to the direction of the magnetic field.[5] Each one of the three sets of g^2 effective (θ) values was computer-fitted, using the mean squares method, to a sinusoidal curve, and from this the amplitude, the minimum value and the position of the latter along the θ axis (first or second quadrant) were obtained. Using the expressions that relate, for each axis 1, 2 and 3, the former data with different g^2_{ij} values,[6] the components of the g^2 symmetric tensor were calculated. The diagonalization of this tensor leads to the values g_{xx}, g_{yy} and g_{zz}. This procedure eliminates the influence on the g values of small errors in the initial orientation of the sample holder in relation to the magnetic field direction.

The spectrum of strongly immobilized randomly oriented $ALMZ^+$ was obtained at 77 K using a sulphuric acid solution (25% by volume) of its perchlo-

* Author to whom correspondence should be addressed.

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rate for a concentration of 1 mg ml^{-1}. A computer program for simulating the EPR spectra of polycrystalline substances, with orthorhombic symmetry and hyperfine coupling with more than one nucleus (assuming parallel g- and A-tensor axes), was used to improve the values of the EPR parameters obtained from this spectrum.

The EPR spectra were recorded with a JEOL PE-3X spectrometer operating in the X band. A Mn–MgO standard was used to calculate the g values.

RESULTS AND DISCUSSION

Single crystal spectra

Using the experimental arrangement indicated above, the EPR signal of an ALMZ$^+$ single crystal at 293 K was measured at different orientations. This signal consists of a single line with a line width of 0.7×10^{-4}–1.0×10^{-4} T depending on the orientation, without any indication of hyperfine splitting. The variation of the measured g values with the orientation for the three rotation axes of the sample holder is presented in Fig. 1. The g_{xx}, g_{yy} and g_{zz} values computed from these data by the procedure described above are presented in Table 1.

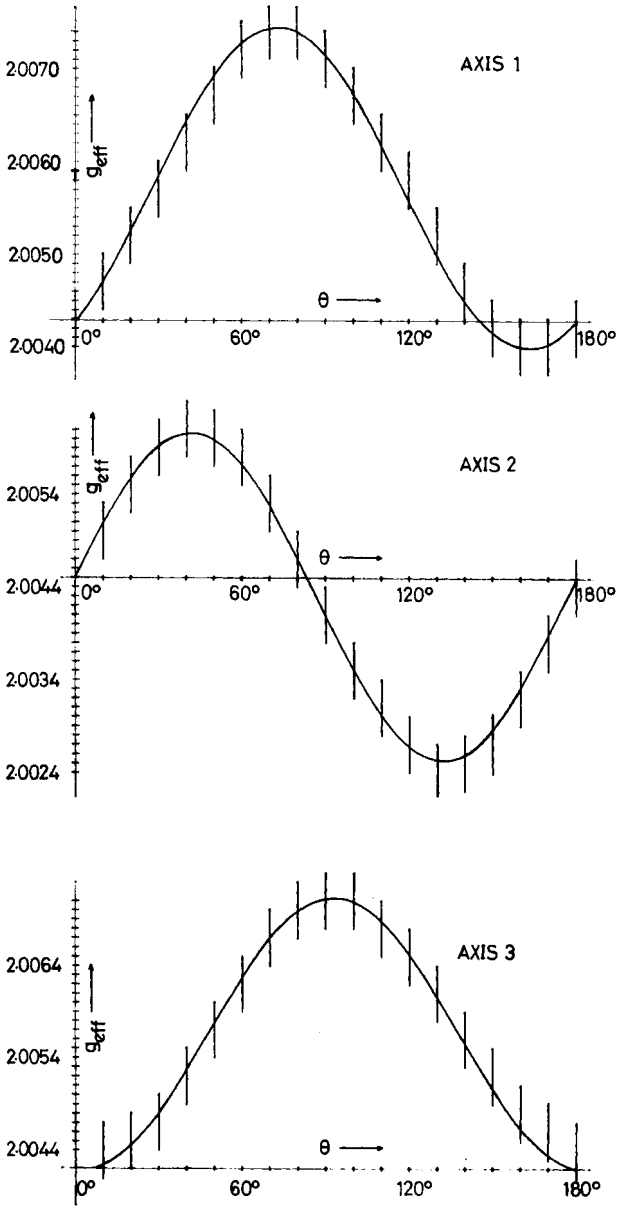

Figure 1. The g-effective values vs the θ angles for different axes of the 1, 2, 3 system. An estimated experimental error of ±0.0003 is represented. The solid line represents the fit curve.

Table 1. EPR parameters obtained for the ALMZ$^+$ radical

	Solution			
	233 K[c]	77 K[d]	Powder	Single crystal[a]
g_{xx}		2.0075	2.0078	2.0075
g_{yy}		2.0059	2.0061	2.0059
g_{zz}		2.0023	2.0022	2.0023
$\bar{g}$			2.0053	2.0052
g_0	2.0053			
$A_0^{\beta H_1}$[b]	1.76	1.8		
$A_0^{\beta H_2}$[b]	5.64	5.6		
A_0^{N}[b]	7.08			
A_{xx}^{N}[b]		3.6		
A_{yy}^{N}[b]		2.0		
A_{zz}^{N}[b]		15.6		
$\Delta H_{pp}(xx)$[b]		4.0		
$\Delta H_{pp}(yy)$[b]		2.4		
$\Delta H_{pp}(zz)$[b]		4.8		

[a] Imprecision of g values, ±0.0003.
[b] Hfsc and ΔH_{pp} values expressed in 10^{-4} T units.
[c] See Ref. 2.
[d] Values used to simulate the strongly immobilized spectrum.

These parameters are close to those obtained for other nitrogen-centred radicals, such as the nitroxides;[7,8] 7.9 in particular, two values are significantly different from g_e, and the third (g_{zz} for the nitroxides) is close to g_e. Thus, it can be assumed that, in ALMZ$^+$, the z axis will also be directed along the 2p(π) orbital of the heterocyclic nitrogen.

The line shape is nearly Lorentzian, indicating that a strong exchange interaction is taking place between the ALMZ$^+$ molecules. This interaction must be the origin of the obliteration of the hyperfine splitting that otherwise, in the absence of any interaction, should appear in the spectrum because of the existence of unpaired electron spin density on the heterocyclic nitrogen.

Powder spectra

The spectra of polycrystalline samples were also recorded at 293 K. These spectra show the signal of a paramagnetic species with a g tensor having orthorhombic symmetry (Fig. 2). Their EPR parameters, checked through computer simulation, are also presented in Table 1. No hyperfine splitting is observed, in agreement with the results obtained with single crystals.

Strongly immobilized spectra in solution

As a method of determining the hyperfine coupling tensor components of the aromatic nitrogen with a

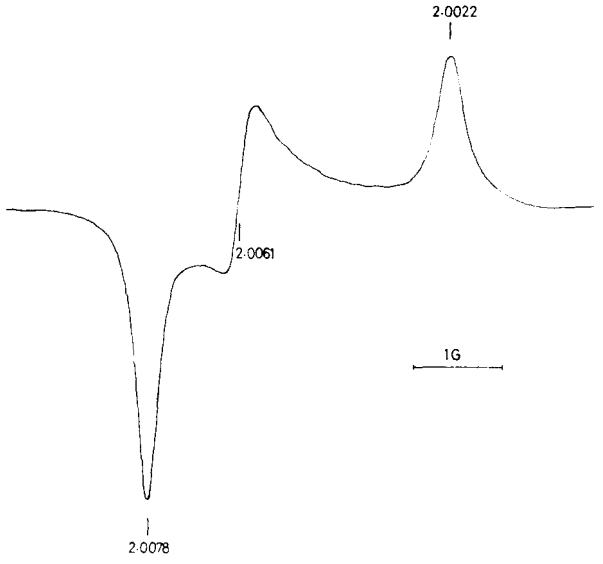

Figure 2. EPR spectrum of $ALMZ^+$ in a polycrystalline sample.

minimum of interactions between the $ALMZ^+$ molecules, the spectrum of $ALMZ^+$ diluted in sulphuric acid solution at 77 K was recorded. At this temperature the solution is frozen, and the EPR spectrum can be interpreted in a similar way to that applied to randomly immobilized nitroxides.[10]

In the case of nitroxides, the A^N tensor is nearly axial, with $A^N_{zz} \gg A^N_{xx} \approx A^N_{yy}$.[7] This is consistent with the half-filled orbital consisting mainly of the nitrogen $2p_z$ orbital, which has cylindrical symmetry. In addition, theoretical calculations indicate that $A^N_{zz} > 0$.[11] On the other hand, the hyperfine couplings with all protons can be assumed to be isotropic. Inspection of the parameters of the liquid solution spectra[2] then shows that all hyperfine couplings, except for those of nitrogen and β-proton 2, must be unresolved in the spectrum shown in Fig. 3a. Therefore, the distance between the extreme peaks in Fig. 3 will be $2A^N_{zz} + A_0^{\beta H_2} \approx 36.90 \times 10^{-4}$ T, where $A_0^{\beta H_2}$ represents the isotropic hfsc due to β-proton 2. The value of this splitting can be taken from the spectrum of $ALMZ^+$ in solution at 233 K since, from a study at different temperatures,[2] it was concluded that at 233 K the spectrum is essentially due to only one conformation. This spectrum, formed by four broad lines, can be simulated using the splitting diagram observed in the spectrum at room temperature, but taking slightly different parameters. The values of the EPR parameters from Ref. 2 that are relevant for this work are presented in Table 1. With $A_0^{\beta H_2} \approx 5.64 \times 10^{-4}$ T obtained in this way, we calculate $A^N_{zz} = 15.63 \times 10^{-4}$ T. Considering that $A^N_0 = 1/3\,(A^N_{zz} + A^N_{yy} + A^N_{xx})$ with $A^N_0 = 7.08 \times 10^{-4}$ T,[2] the values $A^N_{xx} + A^N_{yy} \approx 5.61 \times 10^{-4}$ T and, thus, $A^N_{xx} \approx A^N_{yy} \approx 2.80 \times 10^{-4}$ T are obtained for the other hfsc values. In order to check the reliability of the former procedure and to improve the values obtained for the different parameters, they have been used as initial values to simulate the strongly immobilized spectrum. The computer simulation was made on the basis of the following approximations: (1) the g tensor axes coincide with those of the A^N tensor; (2) the presence of the solvent does not introduce important variations in the g values and, thus, single crystal values can be assumed directly, without change; (3) hyperfine coupling with both β-protons was included and assumed to be isotropic, with the same values as measured in solution. After a process of trial and error, a good concordance between the experimental and simulated spectrum was obtained. In this process different parameters, particularly the nitrogen hyperfine coupling components, have been varied. The best set of values is presented in Table 1 and the simulated spectrum is shown in Fig. 3b. The similarity between the two spectra indicates the reliability of the parameters used in the simulation. This result shows that the hypothesis of a very small influence of the solvent on the g values of the $ALMZ^+$ solution at 77 K is acceptable. The inequality of the A^N_{xx} and A^N_{yy} values indicates that the nitrogen hyperfine coupling tensor has a symmetry which is lower than axial.

Although the g values are very similar to those of the nitroxides, there are some differences in the hfsc values. The unpaired electron spin density is mainly localized in the aromatic nitrogen and preferentially distributed along the nitrogen $2p(\pi)$ orbital, but this density is smaller than in the case of nitroxides, as

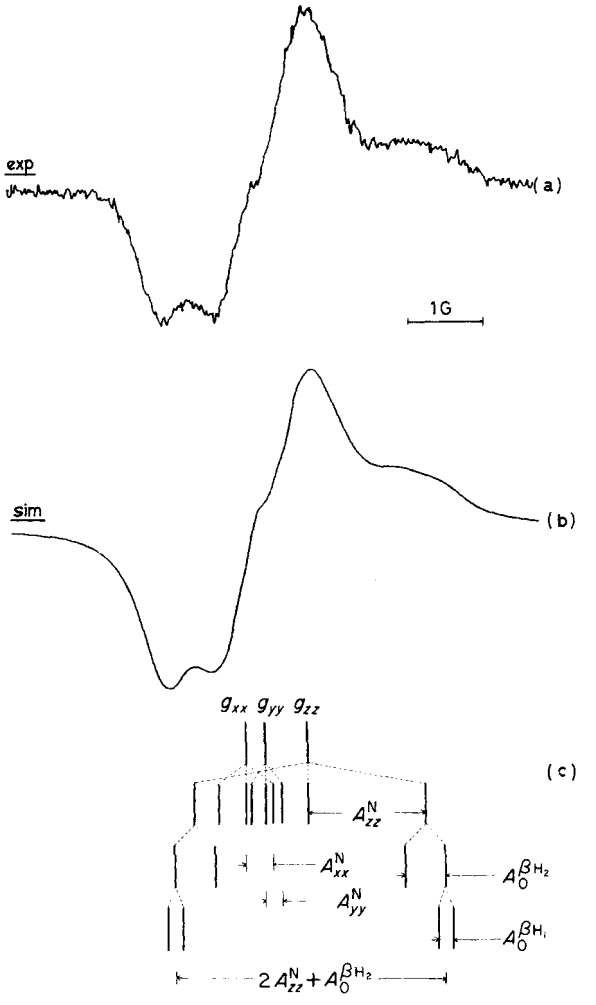

Figure 3. (a) Experimental EPR spectrum of $ALMZ^+$ in sulphuric acid solution at 77 K. (b) Simulated spectrum. (c) Hyperfine splitting pattern.

indicated by the lower A^N values. This fact reflects the electron delocalization in the lateral rings and side chain, and is in agreement with the results in Ref. 12 for the case of chlorpromazine bonded to a nucleic acid.

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