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Positron Annihilation in Benzene, Aniline and Cyclohexane

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Positron annihilation in liquid cyclic hydrocarbons received relatively little experimental attention [1,2]. Cyclohexane, benzene and aniline, in spite of their chemical and structural similarities, seemed to show quite different positron lifetimes: τ_1=142 ps for benzene, τ_1=214 ps cyclohexane and τ_1=204 ps for aniline [2]. The second and third components of lifetimes were reported rather similar τ_2=440-480 ps and τ_3=2.4-3.2 ns with the intensity I_3 of some 33-43%, see [2, 3] for detailed data. Gray *et al.* in the early work [1] searched for the correlation of τ_3 with the molecular polarizability. However, the interaction between thermal positron and molecules is governed by scattering cross sections and the polarizability is only one of the factors influencing the low-energy cross section.

Our measurements of positron scattering in the gas phase performed with the very low-energy apparatus [3] showed that total cross sections in aniline and benzene practically coincide in the 0.5-10 eV energy range while that of cyclohexane is by some 20-30% lower. However, in order to deduce annihilation rates, some extrapolation of cross sections down to thermal energies is needed. We did it recently [4] using modified effective-range theory but the analysis requires some additional input on the scattering length; we used values obtained by Surko and collaborators in their experiments on the annihilation in the gas phase [5]. Cross sections derived in this way in the zero-energy limit [4] contradict our gas phase experiment [3]. This triggered present measurements of annihilation in the liquid phase.

Present measurements were performed with ORTEC PLS system, with RCA 8850 photomultipliers and St. Gobbain BC418 plastic scintillators, assuring a 180-190 ps time resolution. ^{22}Na source encapsulated in 7 μm kapton foil was used. The source immersed in liquid was protected by 25 μm polyethylene foil. Measurements were performed at 295 K. The LT programme by J. Kansy [6] was used to analyse spectra.

Differently to previous measurements [2] we report similar all three components in the lifetime spectra for benzene and aniline (τ_1=174±5 ps and τ_1=181±7 ps, respectively with I_1=22%; τ_2=474±8 ps and τ_2=445±13 ps with I_2=42%; and τ_3=2.14 ns and τ_2=2.25 ns for benzene and aniline respectively). The first and second component in cyclohexane are longer: τ_1=225±6 ps and τ_2=562±14 ps; the third component is similar to aniline, τ_3=2.40 ns, but shows a lower intensity, I_3=30% vs I_3=35%, respectively.

In the gas phase [3] we observed an enhanced cross section at 2-4 eV, i.e slightly above the positronium-formation threshold; this effect was absent in cyclohexane. We speculate on the correlation between the cross section for positronium formation in the gas phase and the τ_3 intensity. Further measurements on other benzene derivates are under way.

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