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Letter to the Editor

STUDY ON POSITRON ANNIHILATION RATE IN WATER

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Abstract. *Measurement system for determination of positron annihilation rate is consisted of HPGe detector, multichannel analyser and Na^{22} positron source. The result of annihilation rate measurement in wetted filter paper is treated. The formula of energy transfer model is used for explanation obtained data quantitatively.*

I. INTRODUCTION

Interaction of positrons in liquids is different from that in solids. As shown by many studies, in liquids positrons acts generally as an acceptor for a quasi-free electron to form positronium so the role of positronium in the radiation chemistry of liquids is especially important.

II. BRIEF DESCRIPTION OF ANNIHILATION PROCESS IN WATER

In principle, there is a number of free electrons in water and in common liquid media so annihilation rate is therefore comparatively small.

When charge particles penetrate into media, a sequence of microregions with a high concentration of the primary radiolysis products emerges along the track of particles. In water, there are primary cation radicals H_2O^+ and electrons with initial energy lower than 8 eV. Such products are very unstable and in a fraction of picosecond, transform into much more long-live OH radicals, hydroxonium ions and solvated electrons localized in "bubbles"(e_{aq})[1,2]:

$$H_2O^+ + H_2O \rightarrow H_3O + OH$$

$$e^- \rightarrow e_{aq} \tag{1}$$

They will be recombined as follows:

$$\mathrm{e_{aq} + e_{aq} = H_2 + 2OH}$$

$$\mathrm{OH{+}OH \rightarrow H_2O_2}$$

These reactions must take a time of 10 ns typically. It is much longer than typical time of positron lifetime, so rather than participating these reactions, a part of e_{aq} electrons will be bound with positrons to form positronium atoms, Ps, and annihilated after that

$$\mathrm{e_{aq} + e^+ \rightarrow Ps} \tag{3}$$

Beside that, there are free electrons created along positron tracks in the medium due to the ionization of molecules caused by positrons. As a charge particle the loss of kinetic energy of positron dT is proportional to thickness of the material dl. On the other side, the absorbed energy in unit mass of material which positrons transfer to the medium, dE is also proportional to dT, so in result dE $\sim$ dT $\sim$ dl. The thickness of sample may be considered in the linear form l or in mass form C. Different from metals and other solid media, in liquids the loss energy is mainly of ionization, so this amount of energy leads to ionization of molecules which liberates electrons along the tracks of positrons and these electrons will be ready to annihilate with positrons or in other words it leads to formation of positron-electron centres. The relation between density of the positron-electron centres n(E) and absorbed energy E can be obtained from the formula of energy transfer model [3]. From the fact that the mass thickness and therefore the absorbed energy is proportional to the water content C in the sample, it leads to

$$n(C) = n_s(1 - e^{-kC}) + n_0 e^{-kC} \tag{4}$$

Here $n_s$is the number of $e^- - e^+$ centres at $C = \infty$, n_0 is the number of $e^- - e^+$ centres at $C = 0$, theoretically. They are proportional to the number of localized electrons (e^-_{aq}) and the number of liberated electron, respectively.

It is needed to emphasize that recombination reaction (2) is a reversal process of $e^+ - e^-$ centres formation and it causes the decrement in the number of $e^+ - e^-$ centres. The coefficient k is the sum of p and q, where p is probability of creation for Ps system by e^- per unit of mass thickness (reaction (2)), and q is probability of destruction of e^- per unit of mass thickness by the other reactions including reaction (2).

III. EXPERIMENT RESULTS

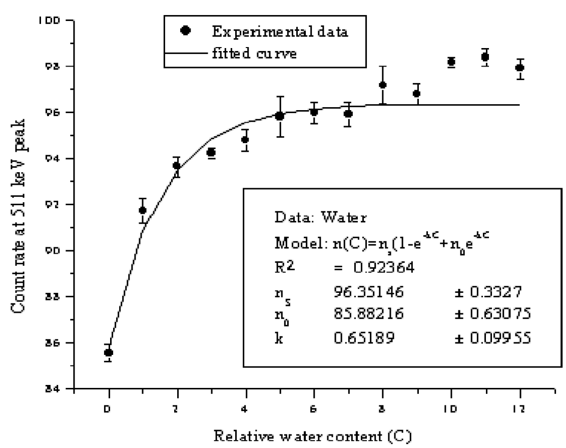

Fig. 1. Experiment result and fitted curve

The experiment is carried out on HPGe detector system with using a 1.5 μCi Na^{22} positron source. By using a micropipet, the content of double distilled water in a filtered paper is ensured to control exactly. The count rate of 511 keV annihilating gamma rays is detected by HpGe detector.

The result of experiment is shown in Fig. 1 where the annihilation rate is drawn against relative water content in samples and R^2 is goodness factor.

IV. DISCUSSION AND CONCLUSION

Experiment result shows that the annihilation rate increases generally with increment of relative water content by an exponential saturation function described by energy transfer model (solid line in Fig. 1).

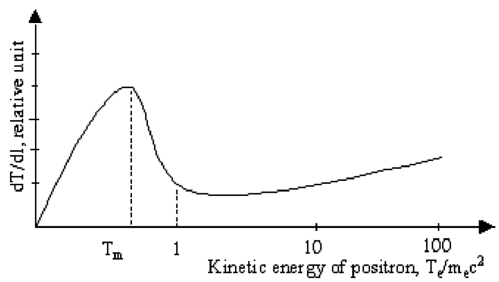

Fig. 2. Bethe curve [4]

The deviation of experimental curve from the theoretical one may be explained by Bethe curve (Fig. 2). Energetic positrons enter the medium with maximum kinetic energy in somewhere around the value 1 where Te $\approx$ 546 keV. During the first stage of energy losing, the energy loss dT/dl is proportionally increased downto Tm, but after that, in the second stage of losing from Tm down to smaller values, dT/dl is decreased, so the energy transferred to the medium is different between two these stages.

In comparison with measurements on aluminium, this data emerges some basic differences. The larger value of coefficient k for aluminium is easily understood from a fact that annihilation rate on aluminium is much larger since larger density of free electrons in metals.

We considered n_0 in formula (4) as the number of e^+-e in the filtered paper without water.

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REFERENCES

1. A. K. Pikaev, A. K. Khim, *Vys. Energ.* **25** (1991) 4.
2. V. I. Grafutin and E. P. Prokop'ev, *Positron Annihilation Spectroscopy in Materials Structure Studies, Physics Uspekhi*, **45** (1) 2002.
3. Tran Dai Nghiep, *Radiation Technology*, Science and Technology Publishing House, Hanoi 2002.
4. I. V. Rakobolskaia, *Nuclear Physics,* Moscow University Press, 1971(in Russian).

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